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DEPARTMENT OF INTERNAL AFFAIRS

STRATIGRAPHY AND PALEONTOLOGY OF THE BLOOMSBURG FORMATION OF PENNSYLVANIA AND ADJACENT STATES

by

Donald M. Hoskins

TOPOGRAPHIC AND GEOLOGIC SURVEY

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DEPARTMENT OF INTERNAL AFFAIRS
Genevieve Blatt, Secretary
TOPOGRAPHIC AND GEOLOGIC SURVEY
Carlyle Gray, State Geologist
1961

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STRATIGRAPHY AND PALEONTOLOGY OF THE BLOOMSBURG FORMATION OF PENNSYLVANIA AND ADJACENT STATES*

by

Donald M. Hoskins

ABSTRACT

The Bloomsburg Formation of Pennsylvania is composed of grayish-red claystone, siltstone, and clayey very-fine to coarse-grained sandstone with small amounts of conglomerate. The sand sized fraction of the rocks is composed predominantly of sutured and strained quartz with some metamorphic and igneous rock fragments. Common accessory minerals are ilmenite, magnetite, and leucoxene, found in both the red and nonred portions of the unit.

Traced to the southwest from the type area, the Bloomsburg Formation thins and is separated into two red-bed units by the marine limestones and shales of the upper member of the Mifflintown Formation. The upper red unit is the Bloomsburg Formation proper, the lower red unit is included in the Mifflintown Formation and is called the Rabble Run Member. The upper portion of the Bloomsburg Formation contains a persistent sandy unit traceable over much of central Pennsylvania. This persistent body is herein named the Moyer Ridge Member of the Bloomsburg Formation. Twenty detailed stratigraphic sections describe the various units.

The Bloomsburg Formation is fossiliferous. Foraminifera, bryozoans, brachiopods, molluscs, ostracods, crinoids, and fish scales have been found in the red beds. All of these groups are rare in occurrence except for the brachiopods and ostracods. Only the Foraminifera, *Lingula* sp. of the brachiopods, and the ostracods are identifiable to at least the genus. Twenty-five species of ostracods, eight of them new, are described from the red beds. Of the new species three are restricted to the red beds.

The Bloomsburg Formation is considered to represent sediments that were deposited in brackish water by streams that carried unreduced hematitic material in the clay-size fraction. The writer feels that the red color was formed in the source area as red soils on a metamorphic terrane rather than post depositionally. The Bloomsburg Formation probably represents part of a large volume of deltaic sediments that were deposited over an area from Virginia into New York and possibly into Northern Michigan. The Bloomsburg sediments are thought to have been deposited in waters sufficiently saline to allow a fauna of brackish character to exist. A few local deposits of nonred, quartzose sandstone are interpreted as bar or beach deposits that were reworked sufficiently to remove the clay and coloring matter.

On the basis of the faunal change near the base of the Moyer Ridge Member of the Bloomsburg Formation, this member and correlative nonred sandstones in Maryland and West Virginia are considered nearly isochronous deposits.

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* Submitted to the Faculty of Bryn Mawr College in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

INTRODUCTION

General Statement

The discovery of numerous ostracods in some red-bed samples from the Bloomsburg Formation of central Pennsylvania prompted this study, the primary purpose of which was to determine the vertical and lateral extent of the fossils in the red beds and to attempt to explain the presence of abundant fossils in what is usually considered to be a barren rock type. It was also hoped that the fossils would permit a closer correlation of the Bloomsburg Formation throughout its outcrop area. Finally, it was thought that data from detailed examination of the fossils and the enclosing rocks might provide some answers to problems associated with the origin of red beds.

An attempt was made to visit every locality in Pennsylvania, Maryland, Virginia, and West Virginia where the Bloomsburg Formation and its equivalent units are well exposed. Some of the localities had been previously described, others were discovered during the present study. In each case the stratigraphic section was measured (or remeasured) and sampled in detail; in particular, each fossiliferous bed was sampled.

Earlier studies of the Bloomsburg Formation, by several authors, had failed to turn up more than a few fossils in the red beds. The present study shows that some of the Bloomsburg red beds contain abundant and varied fossils; this discovery makes necessary a reexamination of the depositional history of these red beds.

Acknowledgements

The writer wishes to acknowledge the financial support for this work by the Pennsylvania Geological Survey and the Committee on the Coordination of Sciences of Bryn Mawr College. The writer also wishes to acknowledge the invaluable aid on taxonomic problems given by Dr. Jean M. Berdan of the U. S. Geological Survey and the technical advice given on mineralogy and petrology by Dr. Dorothy Wyckoff of Bryn Mawr College and Dr. Davis Lapham of the Pennsylvania Geological Survey. The writer also acknowledges the help given by Drs. Lincoln Dryden and Edward Watson of Bryn Mawr College in the preparation of the manuscript and the fossil plates. Type specimens of several ostracod species were made available for photographing and examination by Dr. G. Arthur Cooper of the U. S. National Museum. Dr. Berdan and members of the Pennsylvania Geological Survey, particularly Mr. Richard R. Conlin, have critically read portions of this manuscript.

STRATIGRAPHY

General Statement

The Bloomsburg Formation is a series of red beds that are extensively exposed through eastern and central Pennsylvania. Because it is somewhat more clastic, and hence more resistant than the formations above and below it, good to excellent exposures of the unit are common.

Traced to the southwest from the type area at Bloomsburg, Pa., the Bloomsburg Formation thins, intertongues with gray limestones and shales and, as a result, is defined in other stratigraphic terms (Plate 8 and Figure 6). In the region of Mt. Union-Hollidaysburg, Pa. and southwest from there into Maryland, the red beds are separated into two units by the limestones and shales of the upper member of the Mifflintown Formation. The upper red-bed unit is the Bloomsburg Formation proper; the lower is the Rabble Run Member of the Mifflintown Formation. Throughout much of central Pennsylvania within the upper portion of the Bloomsburg there is a sequence of sandstones and siltstones which usually forms an easily traced ridge. This unit is here designated the Moyer Ridge Member of the Bloomsburg Formation. In the region near Bedford, Pa., and south to near Cumberland, Md., the upper red unit thins further and consists mostly of the beds assigned to the Moyer Ridge Member. Farther south in Maryland and West Virginia the red color of the upper unit is subordinate or nonexistent and the unit is called the Williamsport Member of the Wills Creek Formation. The Williamsport Member and the Bloomsburg Formation contain a thin limestone in the region between Flintstone and Cumberland, Md., and Keyser, W. Va.; this limestone is called the Cedar Cliff Limestone Lentil. One other areally restricted unit is the Bridgeport Sandstone Lentil of the Bloomsburg Formation, found only in Perry County, Pa.

Historical Background

The Bloomsburg Formation was established as a rock unit by I. C. White (1883, p. 106) and was named for good exposures in the town of Bloomsburg, Pa. (Locality 1). The geologic map accompanying White's report was the first to delineate the Bloomsburg Formation. Claypole (1885, p. 51) and White (1885, p. 130) noted the presence of the Bloomsburg Formation but did not map it as a separate unit. D'Invilliers (1891), in Union and Snyder Counties, very accurately mapped the red beds of the Bloomsburg Formation. Stose and Swartz (1912, p. 46) and Swartz (1923a), working in Maryland, placed the Bloomsburg red beds in the Wills Creek Formation as a basal member. The reports of Swartz (1923a, 1923b, 1923c) and Prouty and Swartz (1923) were the first to give a

reasonably accurate description of the Bloomsburg stratigraphy, and to describe the intertonguing of the red beds with marine limestone of the Mifflintown Formation (formerly McKenzie Formation; see Miller, 1961, pp. 11-17 for a discussion of the Mifflintown Formation). Swartz (1923a, p. 36) also named the red beds in the middle of the "Mckenzie Formation" the Rabble Run Member, from the exposures on Rattle Run (formerly Rabble Run), Williamsport quad., Md.; this report also established the limestone lentil found in the Bloomsburg near Cumberland, Maryland, as the Cedar Cliff Limestone (*ibid.*, p. 42). Swartz and Swartz (1931) and F. M. Swartz (1934) described several Pennsylvania sections which include the Bloomsburg Formation; some of these sections were remeasured for this report. A recent comprehensive discussion of the Bloomsburg Formation and its equivalents is that by Woodward (1941, pp. 149-175) who redefined the Williamsport as a formation. Because of its extreme thinness in West Virginia and Maryland, the present writer believes that the Williamsport there should be called a member of the Wills Creek Formation. F. M. Swartz (1946, 1948, 1955, and 1957) discussed the regional aspects and paleogeography of the Bloomsburg Formation.

Terminology

The writer has attempted to use a consistent terminology in describing the measured sections. The lithologic terms in the section descriptions are field terms, established before thin section examination of the various lithologies of the Bloomsburg Formation. Color terms are from the Rock-Color Chart (Goddard and others, 1948).

Bloomsburg Formation

In the area where the Bloomsburg Formation is fossiliferous (Plate 8) the rock types are grayish-red claystone, clayey siltstone, and very-fine- to fine-grained sandstone. The claystone is the predominant rock; Figure 1 shows a typical exposure. In the region to the east of the most fossiliferous area the Bloomsburg contains some coarser rock, the size grades ranging up to medium-grained sandstone with a few beds of coarse sandstone and rare pockets of conglomerate. In this easterly region the greater part of the rock is clayey silty very-fine- to fine-grained sandstone. South and west from the most fossiliferous area the red beds consist mostly of clayey siltstone and clayey silty very-fine-grained sandstone with lesser amounts of claystone.

In all areas the color of the sediment is predominantly grayish-red and ranges between grayish-red (10R4/2) and grayish-red (5R4/2). Some beds of the formation display various olive and gray colors. A few beds exhibit a fine mottling of red and nonred, or an alternation of very thin

Figure 1. A typical outcrop of the Bloomsburg Formation. The upper contact is near the right hand telephone pole. Locality 8.

red and nonred bands; other beds, predominantly red, have spots and zones of colors ranging from moderate reddish-orange to various grays. These are called reduction spots and zones and are assumed to be post-depositional. A few bedding surfaces of grayish claystone have been oxidized and turned red along joint and fracture surfaces; these oxidized portions exhibit the fine banding termed Liesegang bands.

Bedding is well developed in the siltstone and sandstone lithologies. Some of the sandstone beds of the Moyer Ridge Member wedge out within short distances suggesting that they are channel deposits (Figure 2). The claystones do not exhibit good bedding for the most part, and they weather into small fragments. The fossiliferous portions of the claystone are usually bedded, presumably as a result of the increased amount of calcium carbonate provided by the fossils.

Moyer Ridge Member

The resistant sandstone and siltstone beds near the top of the Bloomsburg formation in central Pennsylvania are herein named the Moyer Ridge Member. This member consists of grayish-red, very-fine- to fine-grained sandstone, sandy siltstone and siltstone with a few thin, interbeds of claystone. The Moyer Ridge Member is overlain and underlain by units which consists predominantly of claystone. The Moyer Ridge Member ranges in thickness from about 20 to 50 feet. In a few areas, as at Beavertown (Locality 6), Fort Robinson (Locality 7), Mill Hall (Locality 10), and at Hollidaysburg (Locality 16), the member is not distinguishable. East of the 500 foot isopach (Plate 8) the overlying and underlying units also possess sandstone and siltstone and the distinctiveness of the Moyer Ridge Member is lost. In central Pennsylvania the Moyer Ridge Member is the most commonly exposed part of the Bloomsburg Formation because it nearly everywhere underlies a low ridge.

The type section of the Moyer Ridge Member is located at Mifflintown (Locality 8) on the south flank of the Moyer Ridge anticline where nearly the whole Bloomsburg Formation is well exposed.

F. M. Swartz (1955, p. S-8) applied the name "Lucy School siltstone member" to siltstone in the middle of the Bloomsburg red beds at Mt. Union, Pa. and stated that "this member is persistent from the type area at Mt. Union to Altoona on the west and Lewistown and Mifflintown on the northeast. . . . " Because Swartz has never formally proposed this member name in a publication or given a detailed description of the member at its type section, it is thus not possible to delineate his unit. The Moyer Ridge Member may well include beds previously assigned as Lucy School. In view of the uncertainty the present writer feels it would be better to apply the new name to the unit.

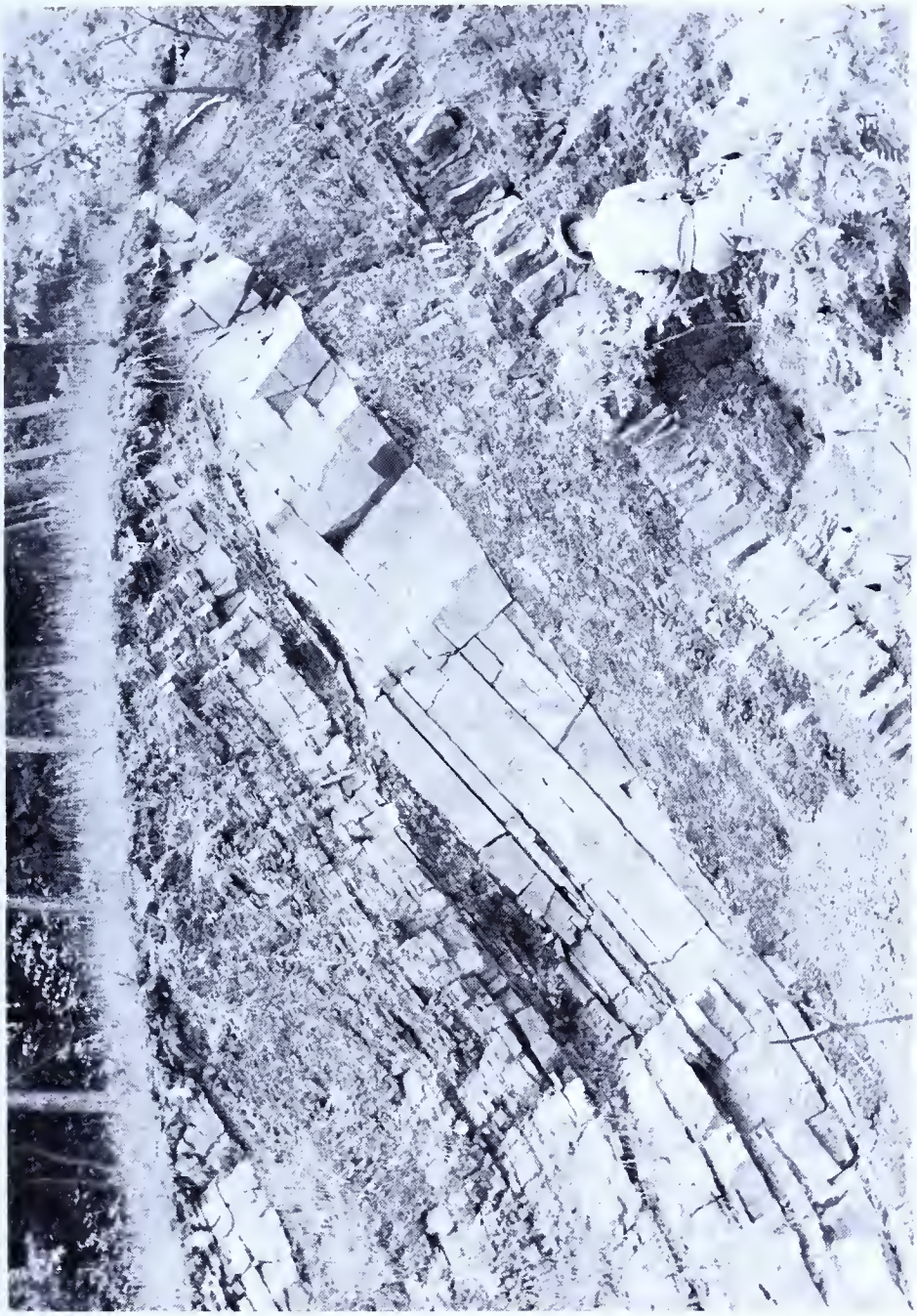

Figure 2. Very-fine-grained sandstone (Moyer Ridge Member) wedging out at the top of the outcrop. Locality 5, unit 4.

Calcareous nodules

Distinctive calcareous claystone nodules enclosed in a much less calcareous claystone matrix can be found just below or interbedded with the Moyer Ridge Member at several localities. These calcareous nodules are best seen at Locality 8, the Mifflintown section, 80 stratigraphic feet below the top of the red beds. (Figures 3 and 4). The nodules are usually present in one bed rarely exceeding a thickness of four feet. The nodules are hard, and range in shape from roughly subspherical, 1 to 2 inches in diameter, to flattened cylindrical, as much as 6 to 8 inches long and 2 to 3 inches at the shortest diameter. The nodules are usually few in number but in some beds they make up more than 80% of the rock; they weather a lighter grayish-red than the enclosing matrix.

Two of the smaller nodules were sectioned to examine their internal structure. The thin-sections show only an increased amount of calcite and hematite over what is usual in thin sections of the normal grayish-red claystone. No internal structures were observed. Calcareous nodules of this type are not restricted to the Bloomsburg Formation, but have been observed in other red bed units in Pennsylvania. The mode of formation of these nodules is unknown.

Petrology of the Bloomsburg Formation

The rocks described as claystones in the section descriptions are composed of from 95 to 99% clay-size material with 1 to 5% subangular quartz usually not exceeding silt size. The rare opaque minerals observed are magnetite, ilmenite, and leucoxene in about equal amounts in the red and nonred portions of the slides. In one slide showing alternation of red and nonred bands the amount of ilmenite and magnetite was slightly greater in the red bands.

The rocks described as siltstones in the section descriptions are clayey siltstones composed of from 50 to 80% angular to subangular silt-size quartz; the remainder is of clay-size. Small amounts of ilmenite and magnetite, along with a few grains of tourmaline and chlorite are present in both the red and nonred siltstones.

The silty very-fine-grained sandstones and the fine-grained sandstones of the Moyer Ridge Member are composed of about 50 to 80% angular to subangular quartz in the very-fine and fine sand sizes with some silt-size fragments; the remainder is clay-size material. A few of the sandstones have less than 5% clay. The opaque minerals magnetite, ilmenite, and leucoxene are slightly more common in the red sandstones than in the nonred. In three thin sections which show a red to nonred transition

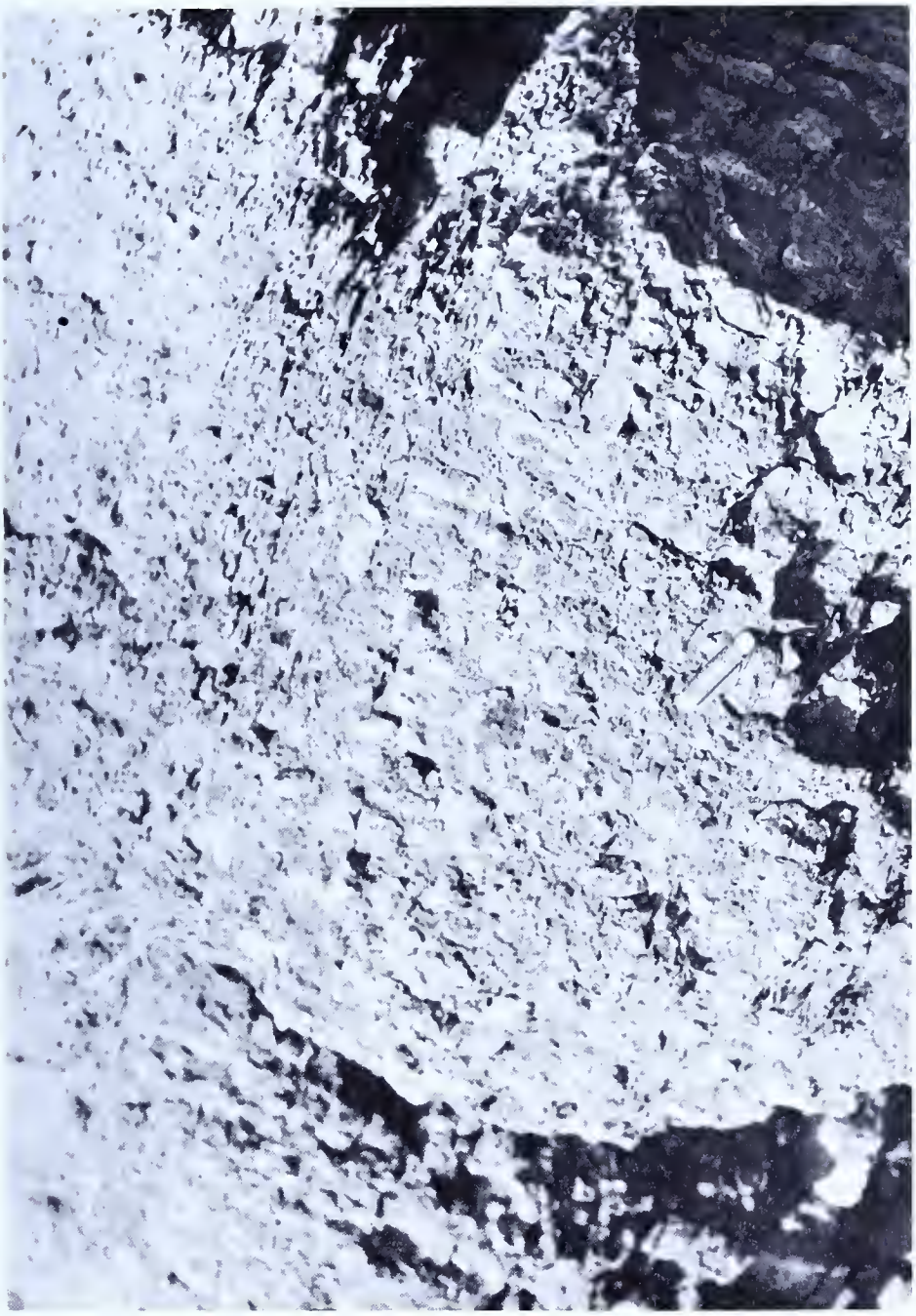

Figure 3. Nodular claystone bed. The nodules weather a lighter color than the enclosing rock. Locality 8, unit 9.

the amounts of magnetite, ilmenite, ilmenite altering to leucoxene, and leucoxene in the red and nonred parts are equal.

Coarser rocks of the Bloomsburg Formation, excluding the Bridgeport Sandstone Lentil, are restricted to the exposures from Harrisburg eastward to the Delaware Water Gap region. These rocks are predominantly clayey, fine to very-coarse sandstone; some specimens bear appreciable amounts of chlorite or carbonate. Conglomerate occurs as pockets and lenses in the finer-grained rocks and in a few beds.

Most of the sandstones are composed of from 70 to 90% strained quartz. Many of the quartz grains are also sutured and some exhibit oriented, secondary regrowths of quartz. Strained K-feldspar is also present in amounts up to 10% of the total composition of the sandstones. A consistent constituent of the Bloomsburg sandstones is microcrystalline aggregates which make up 5 to 10% of the rock. The aggregated quartz exhibits random extinction and strain shadows along the boundaries. The microcrystalline aggregate boundaries may be sharp and rimmed by iron oxide or they may grade into large adjacent grains suggesting fusion by resolution or recrystallization. Many of the aggregates fill the intergranular spaces and appear to have been stretched and compressed into place. Many of the aggregates are identical with those illustrated by Folk (1960, Plate 3, Figures B, D). Folk (p. 10) calls these fragments stretched or recrystallized metaquartzite grains and considers them as evidence of a low-rank metamorphic source. Whether the Bloomsburg aggregates are metaquartzites or not is impossible to determine since at least part of the metamorphic textures are not inherited, but are the result of in situ alteration.

Minor amounts of the following minerals and rock fragments were also observed in the Bloomsburg sandstones: magnetite, limonite, ilmenite, leucoxene, epidote, tourmaline, zircon, muscovite, albite twinned plagioclase in the range Ab_{10}-Ab_{20}, chlorite schist, myrmekitic intergrowth of K-feldspar, and rare claystone. A few vermicular crystals of secondary chlorite were observed.

The presence of fragments of chlorite schist and fragments with myrmekitic texture definitely indicates both a metamorphic and igneous source area. Whether the terrane was predominantly of one type is not possible to determine because the other constituents of the sandstones do not exhibit sufficiently diagnostic criteria to determine the dominant source rock.

Rabble Run Member of the Mifflintown Formation

The Rabble Run Member is continuous with and identical to the lower part of the Bloomsburg Formation. It is predominantly poorly fossiliferous,

grayish-red claystone, except in the area of the type section of the member. At the type section, the Rabble Run (Swartz, 1923a, pp. 96-98) is unfossiliferous grayish-red siltstone and very-fine-grained sandstone.

Williamport Member of the Wills Creek Formation

The Williamsport Member (Reger, 1924, pp. 396-398) is the nonred or nearly nonred lateral continuation of the Bloomsburg Formation south into Maryland and West Virginia. At the type section of the Williamsport Member, a little more than one-half mile east of Williamsport, Grant County, W. Va., the unit is 22 feet thick and is composed of calcareous pale-olive claystone; light-olive-gray (5Y6/1), silty, very-fine-grained sandstone grading to yellow-gray (5Y8/1), very-fine-grained sandstone; and medium-gray, sandy siltstone. Some outcrops of the Williamsport Member expose a few pinkish or reddish beds. The Williamsport Member appears to be in large part the equivalent of the Moyer Ridge Member of central Pennsylvania on the basis of lateral continuation and similar lithology.

Cedar Cliff Limestone Lentil

The Cedar Cliff Limestone Lentil is contained within the Williamsport Member and Bloomsburg Formation in a restricted area in Maryland and West Virginia (Plate 8). It is composed of poorly fossiliferous, dark-gray to medium-dark-gray limestone, argillaceous limestone, and calcareous shale which at some localities is weathered to clay. Thin, very-fine-grained sandstones have also been observed in this unit. Surface weathering of some limestone beds shows that they are composed of intraformational conglomerate.

Bridgeport Sandstone Lentil

The Bridgeport Sandstone Lentil is an areally restricted unit found only in the Loysville quad., which lies mostly in Perry County, Pa. It was named by Claypole (1885, p. 57) for exposures near Bridgeport, where it is thickest and best exposed.

The Bridgeport Sandstone appears about in the middle of the Bloomsburg Formation, and its maximum thickness is 15 feet. It is composed of fine- to coarse-grained quartzose sandstone and clayey, fine- to coarse-grained sandstone with some layers of sandy conglomerate. It is a resistant unit where thickest, and caps some hills. The Bridgeport Sandstone is discontinuous along the strike and may thin and wedge out within one outcrop. Its color ranges from yellowish-gray (5Y8/1) to light-gray; the few clayey beds are grayish-red.

Several thin sections of this rock unit show that it is very similar to the

coarse rocks of the Bloomsburg Formation from the region east of Harrisburg, Pa. The difference is primarily that the clay and fine hematitic coloring matter is absent in the Bridgeport Sandstone.

Examination of the thin sections shows that these clean sandstones are fine to very-coarse sandstone with some granular or pebbly sandstone lenses. In many of the thin sections the size of the originally deposited grains cannot be measured because many of the grains lack outlining coloring matter and because the rock is well cemented; the grains that can be measured show that the sorting is poor. Most if not all of the quartz is strained and sutured and microcrystalline aggregates are common.

The Bridgeport Sandstone Lentil represents an influx of somewhat coarser material than that which is present in the enclosing sediment. It also represents material that was exposed to current action for a sufficient time for the clay and coloring matter that most probably accompanied it to be winnowed out. The Bridgeport may represent beach or bar deposits. To find such a clean sandstone in the midst of predominantly grayish-red claystone and clayey sandstones is unexpected.

Fossiliferous areas

The Bloomsburg Formation is fossiliferous throughout much of the area in which claystones make up the major portion of the red beds (Plate 8). It is not fossiliferous in the region of the type section, nor in the region east of Harrisburg. However, fossil fish fragments have been found by Beerbower and Hait (1959) in the Delaware Water Gap region. The Bloomsburg Formation is also unfossiliferous in the region south of lat. 40° N., with one possible exception mentioned below under PALEONTOLOGY—Historical Background. In the region of Cumberland, Md., and Keyser, W. Va., the Cedar Cliff Limestone Lentil contains a few fossils that are also found in the Bloomsburg Formation of central Pennsylvania.

None of the sandstone or siltstone in the fossiliferous area of the Bloomsburg Formation contain fossils, with the one exception of very poorly preserved pelecypods found on the bedding surface of a sandy siltstone at an outcrop near Lewistown, Pa. (Figure 5). Presumably the environment of deposition of much of the sandstone and siltstone was not favorable for preservation or growth of organisms.

STRATIGRAPHIC SECTIONS

Wherever possible the sections described below were measured directly on the outcrop with a 6-foot tape. Otherwise they were measured by the compass and tape traverse method, and the unit thicknesses were cal-

Figure 4. Nodular claystone bed viewed from above. The nodules make up most of the bed, are up to 8 inches long, and are oriented normal to the bedding surface. Near Lewistown, Pa.

culated trigonometrically. Although the writer feels that the thickness measurements are as accurate as possible under the circumstances, any one section may be a few feet in error.

The color terms used are taken from the Rock-Color Chart (Goddard and others, 1948). The Rock-Color Chart is some places uses the same name for two different but similar colors. Where these colors are employed in the stratigraphic sections, they are followed by their numerical counterpart. All other unduplicated color names are used without the numerical portion. One exception is made to this procedure. The color of most of the Bloomsburg Formation falls into the range of colors grayish red (5R4/2) and grayish red (10R4/2); the difference between these two colors is not pronounced. For these reasons the numerical portions of the colors grayish red are not used to indicate that the Bloomsburg colors generally lie between the two named above.

The following abbreviations are used to indicate fossil abundance: VC-very common, C-common, R-rare, VR-very rare. These terms are based on visual estimation, not statistical counts.

Most of the detailed sections are followed by a short summary of the principal features of the section which presents a brief over-all view of the section unencumbered by the details.

Locality 1.—Bloomsburg, Pa. The type locality

The section at this locality is herein designated as the type section of the Bloomsburg Formation. White (1883, p. 252) mentions this section as the one from which the term Bloomsburg was derived. It is accepted that this locality would have been made the type section had there been such stratigraphic practice at that time. The original description of this section (White, 1883, p. 252) is brief. Because of its importance as the type section, it was judged advisable to remeasure and redescribe the section to fit with current terminology. Unfortunately this section is totally unfossiliferous.

The type section is located one block north of West Main Street on Railroad Avenue, Bloomsburg, Columbia County, Pennsylvania. The exposure begins on the east side of the street and extends northeast along the railroad cut. The section is located 1,000 feet north of lat. 41° N. and 10,500 feet east of long. 76° 30′ W.

The contact of the Bloomsburg and Wills Creek Formations is not exposed, and the presence of housing and lawns precludes the determination of its position. Recent excavation behind the first house south of the railroad on the east side of the street shows that the Bloomsburg Formation is present to this point.

The basal contact of the Bloomsburg Formation is also covered, but nearby outcrops of the Mifflintown Formation, the local topography, and

Figure 5. Fossiliferous siltstone. The bedding surface of the siltstone is covered with small, poorly preserved pelecypods. Near Lewistown, Pa.

the character of the basal beds exposed along the railroad cut indicate that only a small amount is covered.

Estimation of the true thickness of the Bloomsburg Formation at the type locality is difficult because both contacts are concealed. White (p. 252) estimated the thickness to be 450 feet. In the present writer's opinion, partly based on the thicknesses calculated for the Lewisburg and the Selinsgrove sections, the true thickness is nearer 500 feet.

Wills Creek Formation.

Covered.

Bloomsburg Formation.

Upper Member *Unit*	*Unit Thickness*	*Cumulative Thickness*
1. Covered. Thickness estimated.	75	75
2. Claystone, grayish-red, weathers hackly, non-calcareous, exposed behind first house south of railroad.	9	84
3. Covered.	34	118
Moyer Ridge Member		
4. Sandstone, very-fine-grained, and siltstone, grayish-red, from finer to coarser toward unit base, bedding from one-half to 8 inches, reduction spots present irregularly in top 8 feet.	26	144
Lower Member		
5. Claystone, silty, grayish-red, weathers hackly, lower half with irregular calcareous nodules weathering moderate-reddish-orange.	2.5	146.5
6. Sandstone, very-fine-grained, grayish-red, bedding from one-quarter inch to 4 inches.	2.5	149
7. Interbedded claystone, siltstone, very-fine-grained sandstone, grayish-red, upper 40 feet silty claystone.	92.5	241.5
8. Claystone, grayish-red, weathers hackly, partly covered.	11	252.5
9. Interbedded claystone, siltstone, very-fine-grained sandstone, grayish red.	199	451.5
10. Claystone, light-olive-gray (5Y6/1) to medium-light-gray, fissile, with a few 2 to 4 inch interbeds of light-olive-gray (5Y6/1), very-fine-grained sandstone.	7	458.5
11. Claystone, grayish red, weathers hackly.	3	461.5
12. Claystone, light-olive-gray (5Y6/1), fissile, with two inches of medium-light-gray limestone.	1	462.5
13. Repeat unit 11 lithology.	10.5	473
14. Covered. Thickness estimated.	25	498—Total

Mifflintown Formation

Covered.

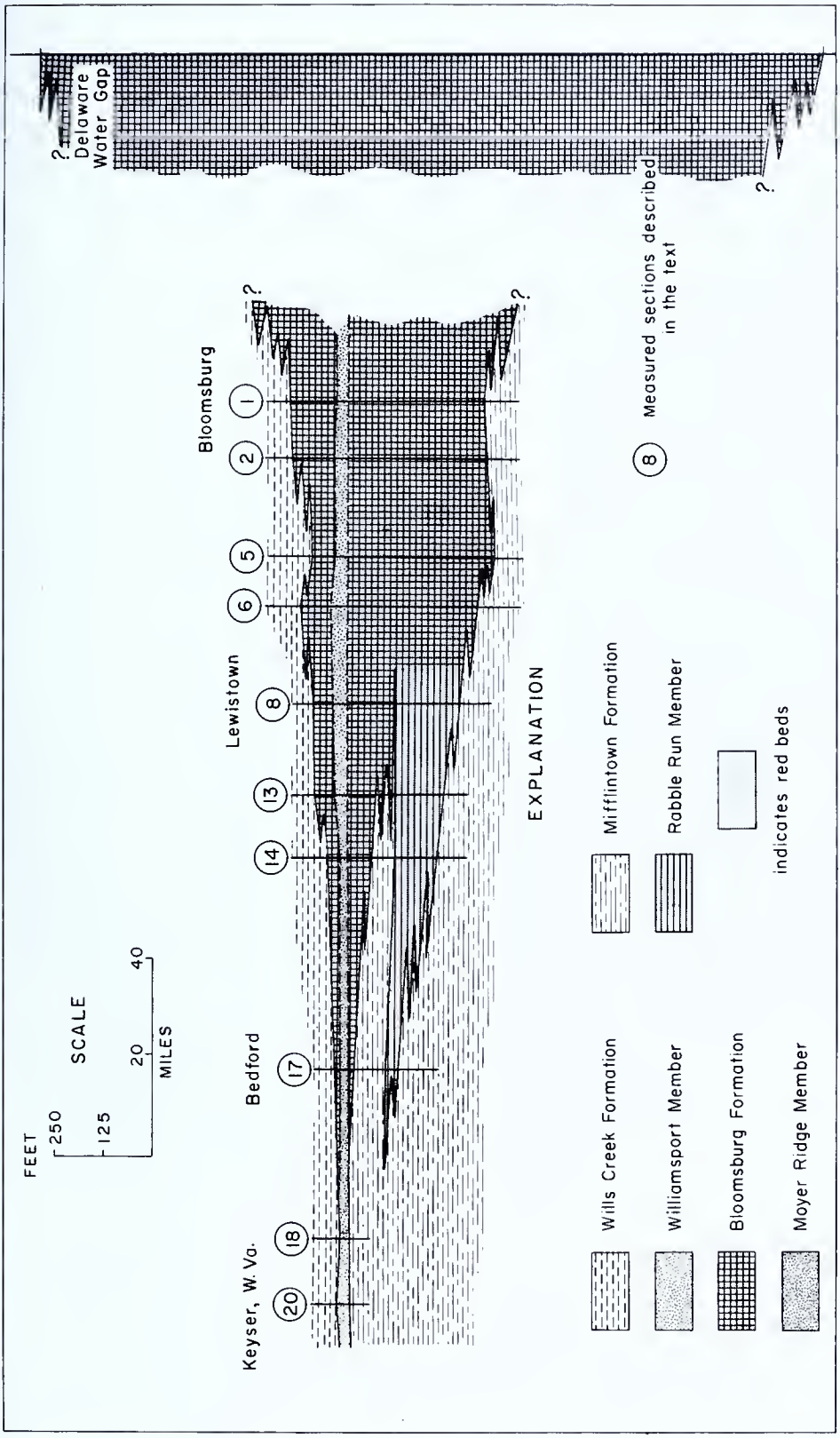

Figure 6. Generalized cross section of the Bloomsburg Formation and its correlative units.

Summary. The over-all lithology of the section is grayish-red, noncalcareous interbedded claystone, siltstone, and very-fine-grained sandstone with a few feet of olive claystones at the base. The rocks are resistant, ridge-forming, and unfossiliferous. The section is covered at the base and top; its true thickness is unknown. The total thickness is estimated as about 500 feet.

Locality 2.—Danville, Pa.

The section exposed on U. S. Route 11, 3 miles west of Danville, Shamokin quad., Northumberland County, Pa., is one of the best exposures of Lower and Middle Silurian rocks in Pennsylvania. The section is located 16,000 feet south of lat. 41° N. and 1,000 feet east of long. 76° 40′ W. Nearly complete exposures are present from the upper beds of the Tuscarora Formation through the Bloomsburg Formation.

According to Swartz and Swartz (1931, p. 629) the Bloomsburg Formation at this locality comprises "Red sandstone and shale. Some thin green beds. *Lingula* sp. (a), 90 feet below top. . . ." The thickness was given as 404 feet exposed. Newer exposures are now available because of widening of the highway at this point.

The Bloomsburg Formation portion of the section is imperfect in two respects. First, the upper contact of the Bloomsburg Formation is completely covered and indeterminable; second, a fault of unknown displacement cuts the red beds. These factors preclude accurate determination of the thickness. It is probable that the thickness of the section approximates that at Locality 1. The thickness of the covered portion at the top of the section and the thickness of the material displaced by the fault are estimated so as to make up the difference between the measured thickness of 398 feet and the probable thickness of about 500 feet. The basal contact is well exposed and is placed at the base of the next to the lowest observed red bed.

The road cut is newer than most others in the Bloomsburg that the writer has observed and as such presents the Bloomsburg Formation in a relatively unweathered state. The difference is especially noticeable in the claystone beds which have not yet weathered in the usual hackly manner.

	Unit Thickness	*Cumulative Thickness*
Wills Creek Formation		
Covered.		
Bloomsburg Formation		
Upper Member		
Unit		
1. Covered. Thickness estimated.	80	80
2. Interbedded silty claystone and sandy siltstone, grayish-red, less sandy and silty toward top of unit. Zones of pale-olive		

Unit	*Unit Thickness*	*Cumulative Thickness*
claystone, 1 to 2 inches thick at 10, 15 and 20 feet below top of unit. Basal 2 feet of unit very-fine-grained sandstone, lower 3 inches are greenish-gray (5GY6/1).	31	111
3. Claystone, silty, grayish-red, weathers hackly, top 1 inch mottled pale-olive.	9	120
Moyer Ridge Member		
4. Sandstone, very-fine-grained, and sandy siltstone, grayish-red, changes thickness along the bed as in a "channel sand."	4	124
5. Claystone, silty, grayish-red, weathers hackly. Thickness of units 4 and 5 mutually vary.	4	128
6. Interbedded sandstone, very-fine-grained, and sandy siltstone, grayish-red, bedding from 4 inches to 3 feet. Lower 1 foot greenish-gray (5GY6/1), very-fine-grained sandstone.	18.5	146.5
Lower Member		
7. Claystone, silty, grayish-red, weathers hackly, poorly preserved fossils at base. Brachiopoda: *Lingula* sp. (R); Ostracoda: *Herrmannina* sp. (VR)	25.5	172
Fault. Fault zone approximately 3 to 5 feet wide. The fault appears to be a reverse fault of small displacement and little stratigraphic cutout.	20?	192
8. Claystone and silty claystone, grayish-red, weathers hackly, some portions calcareous, 5 feet of very-fine-grained sandstone, in beds from 1 to 2 feet, 151 feet below unit top. Poorly fossiliferous zones as noted; 55 feet below top-Ostracoda: *Kloedenia normalis* (C), *Dizygopleura punctella* (R), *Herrmannina* sp. (R); 77 feet below top-Brachiopoda: *Lingula* sp. (C), Articulate brachiopod fragments (R); Ostracoda: *Kloedenia normalis* (R), *Dizygopleura punctella* (C); 110 feet below top-Brachiopoda: *Lingula* sp. (C); Ostracoda: *Kloedenia normalis* (C), *Dizygopleura punctella* (C), *Herrmannina* sp. (R); 215 feet below top-Ostracoda: *Pseudobeyrichia* sp.	264.5	456.5
9. Claystone and thin limestones, greenish-gray (5GY6/1) to medium-light-gray. Brachiopoda: *Lingula* sp. (R).	4.5	461

Unit		Unit Thickness	Cumulative Thickness
10.	Claystone and silty claystone, grayish-red, some portions calcareous.	23.5	484.5
11.	Claystone, greenish-gray (5GY6/1), noncalcareous.	4.5	489
12.	Claystone, grayish-red, noncalcareous. Zone of pale-reddish-brown, calcareous coloration spots 3 feet above base. Medium-gray to greenish-gray (5GY6/1) limestone, mottled with grayish-red at base.	10.5	499.5—Total
Mifflintown Formation			
	Limestone and shale, medium-gray and greenish-gray.		

Summary. The upper contact is hidden. The upper 90 feet of the exposed section is interbedded silty claystone, siltstone, and very-fine-grained sandstone which is separated from the lower Bloomsburg red beds by a fault of unknown displacement and stratigraphic cutout. The lower Bloomsburg Formation consists of 330 feet of grayish-red silty claystone with a few olive beds near the base. The lower portion of the Bloomsburg Formation is poorly fossiliferous in widely separated thin beds. The lower contact is well exposed.

Locality 3.—Milton, Pa.

In the vicinity of Milton, Pa., there are several excellent exposures of the Bloomsburg Formation. Unfortunately, none of the outcrops exposes the upper or lower contact or more than about one-half the total thickness of the formation. To include the maximum amount of stratigraphic interval in the section description, two exposures were measured and the section compiled from both the exposures.

The first exposure on which units 1 to 9 were measured is found along U. S. Route 15, one-quarter of a mile north of West Milton, Milton quad., Union County, Pa. The exposure is 8,900 feet north of lat. 41° N. and 9,300 feet west of long. 76° 50′ W. The second exposure (units 10 to 15) is a cut on the Pennsylvania railroad 100 feet south of the railroad bridge crossing Pa. Route 14, Milton quad., Northumberland County. The cut is 14,200 feet south of lat. 41° 05′ N. and 4,900 feet west of long. 76° 50′ W.

Because the upper and lower contacts are covered, the upper and lower covered intervals are estimated to include a thickness sufficient to make the total thickness agree with the nearby Lewisburg section.

Units 7 to 11 are determinable at both exposures and can be used to correlate from one outcrop to the other. The beds of the second exposure are somewhat more fossiliferous, and the fossils are better preserved.

Wills Creek Formation

Covered.

Bloomsburg Formation

Upper Member *Unit*	*Unit Thickness*	*Cumulative Thickness*
1. Covered. Thickness estimated.	35	35
2. Claystone, grayish-red, weathers hackly.	14	49
3. Covered to partly covered. Grayish-red claystone float and poor exposure. Some dusky-yellow to light-olive-gray (5Y6/1) claystone float.	73.5	122.5
Moyer Ridge Member		
4. Siltstone, sandy, grayish-red, bedding from 2 inches to 2 feet.	32.5	155
5. Claystone, silty, grayish-red, weathers hackly, poorly bedded, bedding from one-half to 3 inches. Middle 3 feet calcareous nodules in claystone matrix. Lower 4 feet grades to very-fine-grained sandstone.	11	166
Lower Member		
6. Claystone, grayish-red, weathers hackly, with 3 feet of interbedded pale-olive and grayish-red calcareous claystone 6 feet below top. Fossiliferous 7 feet below top-Ostracoda: *Kloedenia normalis* (R), *Dizygopleura punctella* (C), *Herrmannina* sp. (R).	29.5	195
7. Claystone, dusky-yellow to pale-olive, weathers hackly, middle portion fissile.	7.5	203
8. Claystone, grayish-red, weathers hackly, calcareous. Fossiliferous 9 feet below top-Ostracoda: *Kloedenia normalis* (C), *Dizygopleura punctella* (C), *Herrmannina* sp. (C), *"Bythocypris"* sp. (VR).	13.5	216.5
9. Claystone, pale-olive, weathers hackly.	5	221.5
10. Claystone, grayish-red, weathers hackly, calcareous, 1 foot very-fine-grained sandstone 3 feet from top. Fossiliferous zones as noted: 19 feet from top-Brachiopoda: *Lingula* sp. (C); Ostracoda: *Kloedenia normalis* (VC), *Kloedenella berdanae* (R), *Dizygopleura punctella* (VR), *Herrmannina* sp. (C); Chordata: ?Agnathid scales. 36 feet from top-Ostracoda: *Kloedenia normalis* (R), *Bolbiprimitia subaequata* (VR), *Herrmannina* sp. (C). 61 feet from top-Bryozoa: gen. and sp. undet. (VR); Ostracoda: *Kloedenia normalis* (R), *Dizygopleura punctella* (R). 83 feet		

Unit	*Unit Thickness*	*Cumulative Thickness*
from top-Ostracoda: *Kloedenia normalis* (VR), *Herrmannina* sp. (C).	86.5	308
11. Claystone, light-olive-gray (5Y6/1) to greenish-gray (5GY6/1), calcareous.	8	316
12. Claystone, grayish-red, weathers hackly, calcareous. Fossiliferous 13 feet from top-Brachiopoda: *Lingula* sp. (R); Ostracoda: *Kloedenia normalis* (VR), *Dizygopleura punctella* (VR), *Herrmannina* sp. (VR). 25 feet from top-Ostracoda: *Kloedenia normalis* (C), *Eukloedenella* sp. (R), *Dizygopleura punctella* (R).	33.5	349.5
13. Repeat unit 11 lithology. Fossiliferous near middle-Ostracoda: *Kloedenia normalis* (R), *Dizygopleura punctella* (VC); Chordata: ?Agnathid scales (C).	8.5	358
14. Repeat unit 12 lithology. Fossiliferous 55 feet below top-Ostracoda: *Dizygopleura punctella* (VR).	108	466
15. Covered. Thickness estimated.	35	501—Total
Mifflintown Formation		
Covered.		

Summary. The upper contact is covered, and the upper 100 feet of the section is predominantly covered. The remaining 400 feet is mostly grayish-red claystone, silty and sandy at the top, with a few thin interbedded units of olive claystone. The lower 350 feet is fossiliferous with many species common, but the preservation is generally poor. The lower contact is covered.

Locality 4.—Lewisburg, Pa.

One-half mile south of Bucknell University, Lewisburg, Pa., along the west bank of the Susquehanna River, a fair section of the Bloomsburg Formation is exposed. The exposure is located 12,000 feet north of lat. 40° 55′ N. and 11,500 feet east of long. 69° 55′ W., Sunbury quad., Union County.

Neither the upper or lower contacts are exposed but it is the writer's opinion based on float evidence, that only a few feet are present in the upper and lower covered intervals.

The section, because of its proximity to the river, is, in places, heavily overgrown. Some of the overgrown units are exposed on the road 100 yards to the west of the river and may also be examined there.

Wills Creek Formation

Covered.

Bloomsburg Formation

Unit	Unit Thickness	Cumulative Thickness
Upper Member		
1. Covered. Thickness estimated.	10	10
2. Claystone, grayish-red, weathers hackly, calcareous, lower 7 feet covered. Fossiliferous 18 feet below top-Brachiopoda: *Lingula* sp. (C); Ostracoda: *Kloedenia normalis* (C), *Dizygopleura halli* (C), *Bolbiprimitia subaequata* (VR).	56	66
Moyer Ridge Member		
3. Sandstone, very-fine-grained, silty, grayish-red, with a few 1 to 2 inch bands of light-olive-gray (5Y6/1) and greenish-gray (5GY6/1) sandstone.	39	105
Lower Member		
4. Claystone, silty, grayish-red, weathers hackly, calcareous, 3 feet of light-olive-gray (5Y6/1), fissile, claystone 58 feet below top. Fossiliferous zones as noted: 24 feet below top-Ostracoda: *Kloedenia normalis* (R), *Kloedenella cristata* (R), *K. gibberosa* (R), *Dizygopleura halli* (R), *D. punctella* (VC), *D. ventrisulcata* (VR); 70 feet below top-Ostracoda: *Kloedenia normalis* (VR), *Dizygopleura punctella* (R), *Herrmannina* sp. (C).	75.5	180.5
5. Claystone, grayish-red, weathers hackly, calcareous, very overgrown, 30% covered, upper few feet covered. Fossiliferous zones as noted: 4 feet below top-Ostracoda: *Kloedenella berdanae* (R), *Dizygopleura punctella* (R); Chordata: ?Agnathid scales (R); 23 feet below top-Brachiopoda: Articulate brachiopod fragments (R); Ostracoda: *Kloedenia normalis* (C), *Kloedenella berdanae* (C), *Herrmannina* sp. (R); 118 feet below top-Ostracoda: *Kloedenia normalis* (C), *Dizygopleura punctella* (C), *Eukloedenella umbilicata* (C); 136 feet below top-Ostracoda; *Kloedenia moralis* (C), *Dizygopleura punctella* (C), *Herrmannina* sp. (R); Chordata: ?Agnathid scales (R); 176 feet below top-Ostracoda: *Kloedenia normalis* (R).	260	440.5
6. Claystone, light-olive-gray (5Y6/1), fis-		

Unit	*Unit Thickness*	*Cumulative Thickness*
sile, calcareous, with 1 foot grayish-red claystone in middle.	4.5	445
7. Claystone, grayish-red, weathers hackly, calcareous, overgrown, lower portion covered.	51	496—Total
Mifflintown Formation		
Covered.		

Summary. The contact of the Bloomsburg and Wills Creek Formations is covered. The upper 60 feet is grayish-red claystone and is abundantly fossiliferous in one thin bed. The upper 60 feet is underlain by 40 fect of ridge-forming very-fine-grained sandstone. The lower 400 feet is grayish-red claystone which is silty at the top, very overgrown, and 30% covered. It is fossiliferous in several thin beds. The lower contact is covered.

Locality 5.—near Selinsgrove, Pa.

In thc southern part of thc Sunbury quad., west of Selinsgrove, the Bloomsburg Formation is exposed in two outcrops about half a mile apart. Measurement of both outcrops permits the compilation and description of much of the Bloomsburg section in the local area.

Outcrop #1 is located in a borrow pit and along a farm lane 3 miles west of Selinsgrove and 0.6 of a mile southeast of Pawling Station. The outcrop is 1,300 feet south of lat. 40°50′ N. and 300 feet west of long. 69° 55′ W. This cxposure shows part of the upper Bloomsburg. Outcrop #2 exposes the lowcr Bloomsburg and is along the east side of the county road 3.5 miles west of Selinsgrove and 0.3 of a mile south of Pawling Station. The outcrop is 1,300 feet south of lat. 40° 50′ N. and 2,600 feet west of long. 69° 55′ W.

The contact of the Bloomsburg and Wills Creck Formations is not seen in outcrop. Detailed field mapping by the writer, previous to this study, permits an accuratc determination of the thickness of the upper covered interval. The contact of the Bloomsburg and Mifflintown Formations is well exposed at outcrop #2.

Units 1-12 are described from outcrop #1 and units 13-20 from outcrop #2. Unit 12 is distinguishable at both exposures and is the unit by which correlation from one exposure to the other is made.

Wills Creek Formation

Covered. Greenish-gray (5GY6/1) to light-olive-gray (5Y6/1) claystone float.

Bloomsburg Formation

Unit		Unit Thickness	Cumulative Thickness
Upper Member			
1.	Covered. Grayish-red claystone float.	61	61
Moyer Ridge Member			
2.	Sandstone, very-fine-grained, grayish-red, jointed, joint surfaces with secondary quartz.	6	67
3.	Interbedded siltstone and claystone, grayish-red, weathers hackly.	8	75
4.	Sandstone, very-fine-grained, grayish-red, varies in thickness, cuts out along bed as in a channel sand.	4	79
5.	Interbedded siltstone and claystone, grayish-red, weathers hackly, with 1 foot very-fine-grained sandstone at base; sandstone greenish-gray (5GY6/1) at base.	4	83
Lower Member			
6.	Claystone, grayish-red, nodular, nodules calcareous and average 1 inch in diameter, basal 1 foot sandy siltstone, siltstone greenish-gray (5GY6/1) at base.	5	88
7.	Claystone, grayish-red, weathers hackly, calcareous, 1 foot pale-olive claystone 20 feet below top. Fossiliferous zones as noted; 16 feet below top-Ostracoda: *Kloedenia normalis* (VR), *Kloedenella cristata* (R), *Dizygopleura halli* (C), *D. punctella* (VC), *D. ventrisulcata* (R), *Herrmannina* sp. (R), *"Bythocypris"* sp. (VR); 43 feet below top-Gastropoda: Gen. and sp. undet. (VR); Ostracoda: *Kloedenia normalis* (R), *Kloedenella cristata* (C), *Eukloedenella curta* (C), *Dizygopleura punctella* (VC).	45	133
8.	Covered. Grayish-red claystone float.	10.5	143.5
9.	Claystone, grayish-red, weathers hackly, middle 7 feet sandy siltstone with bedding from 1 to 4 inches. Fossiliferous 20 feet from top-Ostracoda: *Kloedenia normalis* (R), *Dizygopleura punctella* (VR).	22	165.5
10.	Covered. Grayish-red claystone float.	25	190.5
11.	Claystone, grayish-red, weathers hackly, calcareous. Fossiliferous 2 feet from top-		

Unit	*Unit Thickness*	*Cumulative Thickness*
Ostracoda; *Kloedenia normalis* (C), *Dizygopleura punctella* (VR), *Herrmannina* sp. (R); 44 feet from top-Ostracoda: *Kloedenia normalis* (VR), *Dizygopleura punctella* (VR).	45.5	236
12. Claystone, light-olive-gray (5Y6/1), somewhat fissile, calcareous, contains 1 to 2 inch fossiliferous limestone at exposure #2. Brachiopoda: Articulate brachiopod fragments; Ostracoda: *Velibeyrichia mesleri* (VR), *Kloedenia normalis* (R), *Kloedenella gibberosa* (C), *Eukloedenella umbilicata* (VR), *Dizygopleura punctella* (C), *D. ventrisulcata* (VR): Chordata: ?Agnathid scales (VR).	4.5	240.5
13. Repeat unit 11 lithology.	20	260.5
14. Covered. Valley.	73	333.5
15. Repeat unit 11 lithology. Fossiliferous 13 feet below top-Bryozoa: Gen. and sp. undet. (R); Ostracoda: *Kloedenia normalis* (R), *Dizygopleura punctella* (R).	14	347.5
16. Repeat unit 11 lithology. Upper 5 feet covered.	14	361.5
17. Covered.	29	390.5
18. Claystone, grayish-red, weathers hackly with a few inches of light-olive-gray (5Y6/1) fissile claystone at top. Lower 20 feet covered.	55	445.5
19. Interbedded siltstone and claystone, grayish-red, top 1 foot light-olive-gray (5Y6/1), *Lingula* sp. (R) at top.	22.5	468—Total
Mifflintown Formation		
Top 2 feet covered. Intermittent exposure for several feet of interbedded medium-gray limestone and shale.		

Summary. The upper contact and the upper 60 feet are covered. The upper covered interval is underlain by 30 feet of very-fine-grained sandstone. The lower 400 feet of the section is predominantly grayish-red claystone which is fossiliferous in widely separated thin beds. The fossiliferous beds in unit 7 bear abundant and well preserved ostracods. The lower 200 feet is 50% covered. The basal contact is well exposed.

Locality 6.—Beavertown, Pa.

A nearly complete section of the Bloomsburg Formation is exposed in the quarries of the Glen Gery Brick Company 0.7 of a mile south of

Beavertown, Pa. The quarries are located 3,500 feet south of lat. 40° 45′ N. and 4,000 feet west of long. 77° 10′ W., in the Millerstown quad., Snyder County.

The described section is pieced together from the exposures in the various quarries; some of the quarries are abandoned and some are currently operated. The contact of the Bloomsburg and Wills Creek Formations is exposed in the creek bank 40 feet north of the most northerly quarry. Unit 1 was measured along the creek; the remaining units were measured in the quarries.

The section is nearly complete with the exception of a short covered interval between the two main quarries and a covered interval obscuring the basal contact. The lower Bloomsburg is exposed in the currently active quarry, and it is anticipated that this quarry will be widened; thus uncovering the basal contact. The Moyer Ridge Member of other areas is not distinguishable in this section.

Wills Creek Formation

Claystone, light-olive-gray (5Y5/2), fissile, calcareous.

Bloomsburg Formation

Unit	*Unit Thickness*	*Cumulative Thickness*
1. Claystone, grayish-red, weathers hackly, calcareous, 6 inches dusky-yellow claystone at base.	26	26
2. Claystone, grayish-red, weathers hackly, upper portion calcareous, lower portion non-calcareous and silty. Fossiliferous 26 feet below top-Ostracoda: *Pseudobeyrichia* sp. (VR), *Kloedenia normalis* (C), *Dizygopleura halli* (C), Chordata: Heterostracid scales (R). Lower 30 feet questionably equals The Moyer Ridge Member.	94	120
3. Siltstone, sandy, grayish-red, top 2 feet calcareous nodular claystone, top 2 inches of claystone greenish-gray (5GY6/1).	6.5	126.5
4. Claystone, grayish-red, weathers hackly, calcareous. Fossiliferous zones as noted: at top-Ostracoda: *Kloedenia normalis* (C), *Bolbiprimitia subaequata* (C), *Kloedenella cristata* (C), *Eukloedenella curta* (C), *Dizygopleura punctella* (VC), *D. ventrisculata* (C), *Herrmannina* sp. (R), *"Bythocypris"* cf. *"B." pergracilis* (R); 49 feet from top-Ostracoda: *Kloedenia normalis* (R), *Kloedenella berdanae* (R),		

Unit		*Unit Thickness*	*Cumulative Thickness*
	Eukloedenella sp. (C), *Dizygopleura punctella* (VR), *D. ventrisulcata* (VR), *Herrmannina* sp. (VR); Chordata: ?Agnathid scales (VR); 60 feet below top-Brachiopoda: Articulate brachiopod fragments (R), *Lingula* sp. (C); Ostracoda: *Velibeyrichia mesleri* (VR), *Kloedenia normalis* (C), *Kloedenella berdanae* (C), *Eukloedenella umbilicata* (R).	60.5	187
5.	Claystone, light-olive-gray (5Y5/2), calcareous.	3.5	190.5
6.	Repeat unit 4 lithology. Fossiliferous 7 feet below top-Ostracoda: *Velibeyrichia mesleri* (R), *V. tricornia* (R), *Kloedenia normalis* (C), *Kloedenella berdanae* (C), *K. gibberosa* (VR), *Dizygopleura ventrisulcata* (R), *Herrmannina* sp. (VC), *"Bythocypris" philipsiana* (R).	9.5	200
7.	Claystone, light-olive-gray (5Y5/2), calcareous.	2	202
8.	Covered. Intermittent exposure and float shows grayish-red claystone.	37	239
9.	Repeat unit 4 lithology.	10.5	249.5
10.	Claystone, light-olive-gray (5Y6/1) to greenish-gray (5GY6/1), calcareous.	6.5	256
11.	Repeat unit 4 lithology. Fossiliferous zones as noted: 5 feet below top-Brachiopoda: *Lingula* sp. (VR); Ostracoda: *Kloedenia normalis* (R). *Herrmannina* sp. (C); 26 feet below top-Ostracoda: *Kloedenia normalis* (VC), *K. gibberosa* (VC), *Eukloedenella* sp. (VC), *Dizygopleura punctella* (VC), *Herrmannina* sp. (R); Chordata: ?Agnathid scales; 35 feet below top-Ostracoda: *Kloedenia normalis* (C), *Dizygopleura punctella* (C); 54 feet below top-Foraminifera: ?*Bathysiphon* cf. *B. exiguus* (VR); Ostracoda: *Kloedenia normalis* (C), *Kloedenella gibberosa* (R), *Dizygopleura punctella* (R); 62 feet below top-Ostracoda: *Kloedenia normalis* (R), *Dizygopleura punctella* (R), *"Bythocypris" philipsiana* (R); 95 feet below top-Brachiopoda: *Lingula* sp. (R); Ostracoda: *Kloedenia normalis* (VR), *Herrmannina* sp. (R); Chordata: ?Agnathid scales (VR); 126 feet below top-Ostracoda: *Kloedenia*		

Unit	Unit Thickness	Cumulative Thickness
normalis (R), *Kloedenella gibberosa* (R), *Herrmannina* sp. (VR).	127	383
12. Claystone, light-olive-gray (5Y6/1) to greenish-gray (5GY6/1), calcareous.	4	387
13. Repeat unit 4 lithology.	43	430
14. Covered. Thickness estimated.	20	450—Total
Mifflintown Formation		
Covered. Exposed 200 feet south of Bloomsburg quarry in old abandoned quarry.		

Summary. The Bloomsburg Formation at Beavertown is essentially a continuous series of grayish-red claystones somewhat silty at the top but lacking the usual sandstone found near the top of the Bloomsburg. A few olive claystones are present. The section is moderately fossiliferous, and some of the fossiliferous beds in units 4 and 11 contain immense numbers of well preserved individuals. The lower contact is covered.

Locality 7.—Fort Robinson, Pa.

The Bloomsburg Formation section at Fort Robinson, Loysville quad., Perry County, Pa., is exposed starting at a point about 200 feet west of the road junction at Fort Robinson along Pa. Route 274. The section is 9,400 feet north of lat. 40° 20′ N. and 9,000 feet east of long. 77° 25′ W.

The contact of the Bloomsburg and Wills Creek Formations is covered but has been determined by detailed mapping by Miller (1961). This upper contact is placed at the old, abandoned railway bed about 100 feet north of the highway where units 2 and 3 are exposed.

Approximately 60% of the total section is well exposed at this locality; the remaining 40% is either partially or totally covered. The Moyer Ridge Member is not distinguished in this section. The basal contact is well exposed and is placed at the base of the lowest observed red bed. Swartz and Swartz (1931, p. 626) described the Bloomsburg Formation at this locality as follows: "Red sandstone and shale and red soil. Some green beds especially in lower part . . . 500 feet."

Wills Creek Formation		
Covered.		
Bloomsburg Formation		
Unit	Unit Thickness	Cumulative Thickness
1. Covered. Lower 30 feet partially exposed west along road. Grayish-red claystone and siltstone.	104	104

Unit	*Unit Thickness*	*Cumulative Thickness*
2. Partly covered. Intermittent exposures of interbedded, grayish-red claystone, siltstone and very-fine-grained sandstone. A 6 inch zone of calcareous nodules 17 feet below top.	54.5	158.5
3. Interbedded claystone, weathers hackly, siltstone, and very-fine-grained sandstone, all grayish-red, 9 feet covered starting 11 feet below top.	37	195.5
4. Covered. Small gully.	6	221.5
5. Partly covered. Interbedded claystone, weathers hackly, and siltstone, grayish-red, some portions calcareous, 5 feet above base 1 foot dusky-yellow, very-fine-grained sandstone. Unit very overgrown and poorly exposed, marked by automobile pull off area. Fossiliferous 39 feet below top-Brachiopoda; Articulate brachiopod fragments; Ostracoda: *Velibeyrichia mesleri* (C), *Kloedenia normalis* (C), *Kloedenella berdanae* (C), *Herrmannina* sp. (R).	42	263.5
6. Interbedded claystone, weathers hackly, siltstone, and argillaceous very-fine-grained sandstone, grayish-red. Basal 10 feet covered. Fossiliferous 20 feet below top-Brachiopoda: *Lingula* sp. (C); 33 feet below top-Ostracoda: *Kloedenia normalis* (C), *Eukloedenella umbilicata* (VR), *Dizygopleura punctella* (C), *"Bythocypris" philipsiana* (VR).	44.5	308
7. Interbedded claystone, weathers hackly, siltstone, and argillaceous very-fine-grained sandstone. Fossiliferous 4 feet below top of unit-Brachiopoda: *Lingula* sp. (C).	81	389
8. Covered. Small valley.	41.5	430.5
9. Interbedded claystone, weathers hackly, siltstone, and argillaceous very-fine-grained sandstone, grayish-red, some portions calcareous, 2 feet medium-light-gray, calcareous claystone 8 feet from top. Fossiliferous 36 feet below top-Brachiopoda; *Lingula* sp. (R); Ostracoda: *Kloedenella gibberosa* (VR), *Eukloedenella* sp. (R), *Herrmannina* sp. (VR). Basal 5 feet covered. Unit base at culvert.	42.5	473
10. Interbedded very-fine-grained sandstone and silty sandstone, grayish-red. Top		

Unit	*Unit Thickness*	*Cumulative Thickness*
one-half foot light-olive-gray (5Y6/1) claystone.	7	480
11. Partly covered to covered, interbedded claystone and siltstone, grayish-red and light-olive-gray. Fossiliferous 3 feet below top-Ostracoda: *Kloedenella gibberosa* (VR).	13	493
12. Sandstone, very-fine-grained, argillaceous, grayish-red, jointed.	8	501—Total
Mifflintown Formation		
Medium-dark-gray claystone and limestone.		

Summary. The upper contact and the upper one-fifth of the Bloomsburg Formation is covered. The remaining portion of the section is interbedded very-fine-grained sandstone, siltstone, and claystone which is grayish-red with a few olive beds near the base. Within the section the fossils are poorly preserved, few in numbers, and are found at only a few horizons. The basal contact is well exposed.

Locality 8.—Mifflintown, Pa.

The Bloomsburg section at Mifflintown is located along U. S. Route 22, about 150 yards north of the town line of Mifflintown, Mifflintown quad., Juniata County, Pennsylvania. The section is 2,800 feet south of lat. 40° 35′ N. and 5,200 feet east of long. 77° 25′ W.

This section is very well exposed and is easily accessible. The contact of the Wills Creek and Bloomsburg Formations is visible at the south end of the exposure. The basal contact of the Bloomsburg Formation is covered but is located by detailed mapping at the culvert a few feet north of the lowest Bloomsburg exposure. This outcrop represents one of the best sections of the Bloomsburg Formation in central Pennsylvania and in it can be seen the various types of lithology that make up the great bulk of the unit. The Mifflintown section is also one of the most fossiliferous sections encountered in this study, and many of the well preserved fossils were obtained here. This exposure is chosen as the type section of the Moyer Ridge Member.

Wills Creek Formation

Claystone, pale-olive, grayish-olive and dusky-yellow, somewhat fissile, portions calcareous.

Bloomsburg Formation

Unit	*Unit Thickness*	*Cumulative Thickness*
Upper Member		
1. Claystone, grayish-red, weathers hackly, slightly calcareous. In middle 1 foot of mottled grayish-red and yellowish-gray, calcareous claystone. At base 1 foot of dusky-yellow-green, fissile claystone.	9	9
2. Claystone, grayish-red, weathers hackly, calcareous. At top 9 inches of mottled dusky-yellow and grayish-red calcareous claystone.	3.5	12.5
3. Claystone, mottled grayish-red and light-olive-gray (5Y6/1), very calcareous, resistant.	1	13.5
4. Claystone, grayish-red, weathers hackly, calcareous. At top 6 inches of dusky-yellow claystone. In middle 6 inches of greenish-gray (5GY6/1), very calcareous claystone with *Herrmannina* sp. (C).	7.5	21
5. Claystone, grayish-red and greenish-gray (5GY6/1), very calcareous. Very fossiliferous-Brachiopoda: *Lingula* sp. (R); Pelecypoda: gen. and sp. undet. (VR); Ostracoda: *Kloedenia normalis* (VC), *Bolbiprimitia subaequata* (VR), *Eukloedenella* sp. (VR), *Dizygopleura halli* (VC), *Herrmannina willsensis* (R), Chordata: Heterostracid scales (C).	3	24
6. Claystone, grayish-red, weathers hackly, non-calcareous. In lower few feet many small, undulatory fractures sub-parallel to bedding, with very thin calcite fillings.	15.5	39.5
Moyer Ridge Member		
7. Claystone, silty, and siltstone, grayish-red, weathers hackly. Beds of silty, very-fine-grained sandstone at top and 1 foot from base.	9	48.5
8. Interbedded siltstone and silty, very-fine-grained sandstone, claystone at base, grayish-red. Bedding from one-half to 3 inches. Greenish-gray (5GY6/1) to pale-olive and moderate-orangish-red reduction spots and thin zones, some reduction spots calcareous.	31.5	80

Unit	*Unit Thickness*	*Cumulative Thickness*
Lower Member		
9. Claystone, grayish-red, calcareous, nodular. Nodules very hard, built on a dense calcareous core. Ratio of nodules to matrix decreases upward from about 3:1 at base to 1:2 at top.	4	84
10. Claystone and siltstone, grayish-red, weathers hackly. Greenish-gray (5GY6/1) zones at base and 1 foot above base.	5.5	89.5
11. Claystone, grayish-red, weathers hackly, calcareous. Fossiliferous in middle and base-Ostracoda: *Kloedenia normalis* (VC), *Bolbiprimitia subaequata* (C), *Kloedenella cristata* (C), *Dizygopleura punctella* (VC), *D. ventrisulcata* (R), *Eukloedenella* sp. (C), *Herrmannina* sp. (R), *"Bythocypris"* cf. *"B." pergracilis* (C).	6	95.5
12. Covered. Small gully.	13.5	109
13. Repeat unit 11 lithology. Fossiliferous 2 feet below top-Brachiopoda: *Lingula* sp. (C); Ostracoda: *Kloedenia normalis* (R), *Bolbiprimitia subaequata* (R), *Dizygopleura punctella* (VC), *Herrmannina* sp. (C); Chordata: ?Agnathid fragments (VR); 17 feet below top-Bryozoa: gen. and sp. undet. (R); Ostracoda: *Pseudobeyrichia simplex* (R), *Kloedenia normalis* (C), *Bolbiprimitia subaequata* (R), *Kloedenella gibberosa* (VR), *Eukloedenella curta* (C), *Dizygopleura punctella* (C), *D. ventrisulcata* (VR), *Herrmannina* sp. (VR), *"Bythocypris"* cf. *"B." pergracilis* (R); Crinoidea: crinoid columnals (VR); lower 8 feet-Brachiopoda: Articulate brachiopod fragments (VR); Bryozoa: gen. and sp. undet. (VR); Ostracoda: *Velibeyrichia mesleri* (VR), *Pseudobeyrichia simplex* (R), *Kloedenia normalis* (R), *Kloedenella berdanae* (C), *Eukloedenella curta* (C), *Dizygopleura punctella* (C), *D. ventrisulcata* (R), *Herrmannina willsensis* (C).	31.5	140.5
14. Claystone, light-olive-gray (5Y5/2), partly fissile, part weathers hackly, calcareous with a few interbeds of medium-light-gray limestone in beds up to 3 inches thick, basal 3 feet partly covered. Fossiliferous		

Unit		*Unit Thickness*	*Cumulative Thickness*
	2 feet below top-Brachiopoda: Articulate brachiopod fragments (VR); Bryozoa: gen. and sp. undet. (VR); Ostracoda: *Velibeyrichia mesleri* (VR), *Kloedenia normalis* (R), *Kloedenella berdanae* (C), *Eukloedenella* sp. (R), *Dizygopleura punctella* (C), *"Bythocypris" philipsiana* (R); 8.5 feet below top-Bryozoa: gen. and sp. undet. (VC); Ostracoda: *Velibeyrichia tricornia* (R), *Kloedenia normalis* (R), *Kloedenella berdanae* (C); Crinoidea: crinoid columnals (C).	8.5	149
15.	Claystone, grayish-red, weathers hackly, calcareous. Upper 5 feet and lower 8.5 feet partly covered. A few 2-inch beds of medium-light-gray limestone near top. Just above lower covered portion 3 feet light-olive-gray (5Y5/2) fissile claystone. Fossilifcrous 11 feet from top-Bryozoa: gen. and sp. undet. (R); Ostracoda: *Velibeyrichia mesleri* (C), *Kloedenia normalis* (C), *Kloedenella gibberosa* (C), *K. berdanae* (R), *Eukloedenella sinuata* (VR), *Herrmannina* sp. (R), *"Bythocypris" philipsiana* (VR); 22 feet from top-Brachiopoda: Articulate brachiopod fragments (VR); Ostracoda: *Velibeyrichia mesleri* (R) *V. tricornia* (R), *Dibolbina lobata* (VR), *Kloedenia normalis* (R), *Kloedenella gibberosa* (R), *K. berdanae* (VR), *Herrmannina* sp. (VR); 43 feet from top-Brachiopoda: Articulate brachiopod fragments (VR); Bryozoa: gen. and sp. undet. (VR); Ostracoda: *Velibeyrichia mesleri* (VR), *Kloedenia normalis* (C), *Kloedenella berdanae* (VC), *Dizygopleura punctella* (C), *Herrmannina* sp. (R).	45	194
16.	Claystone, light-olive-gray (5Y5/2) fissile, calcareous. Middle 3 feet of unit covered. At base 1 foot grayish-red claystone.	16.5	210.5
17.	Claystone, grayish-red, weathers hackly, calcareous in upper 40 feet. Fossiliferous 9 feet below top-Ostracoda: *Pseudobeyrichia ventrilirata* (VR), *Kloedenia normalis* (VC), *Kloedenella gibberosa* (R), *Eukloedenella umbilicata* (VC), *Dizygo-*		

Unit	Unit Thickness	Cumulative Thickness
pleura punctella (VC), *Herrmannina* sp. (R); 17 feet below top-Coelenterata: *Favosites?* sp. (VR); Brachiopoda: *Lingula* sp. (R); Bryozoa: gen. and sp. undet. (R); Ostracoda: *Kloedenia normalis* (VC), *Eukloedenella umbilicata* (C), *Dizygopleura punctella* (C), *Herrmannina* sp. (VR); Chordata: ?Agnathid fragments (R); 32 feet from top-Ostracoda: *Kloedenia normalis* (VR), *K. gibberosa* (C), *Dizygopleura punctella* (R), *Herrmannina* sp. (VR); 85 feet from top-Ostracoda: *Kloedenia normalis* (C), *Dizygopleura punctella* (C), *Herrmannina* sp. (R).	89.5	300
18. Partly covered float bank. Grayish-red, non-calcareous claystone.	33	333
19. Covered. Small valley and stream. Contact of Bloomsburg and Mifflintown Formations estimated at stream.	30	363—Total
Mifflintown Formation		
Covered.		

Summary. The upper 40 feet of the Bloomsburg Formation is mostly grayish-red, calcareous claystone with some olive units, with one unit very fossiliferous. The upper contact is well exposed. Below the upper claystone is 40 feet of siltstone and very-fine-grained sandstone of the Moyer Ridge Member which is resistant and ridge-forming. The remaining 280 feet of the section is grayish-red, calcareous claystone with many of the units very fossiliferous. The fossils are abundant and well preserved. The lower 60 feet is covered, and the basal contact is not visible.

Locality 9.—Licking Creek Valley, Pa.

The best Bloomsburg section in Licking Creek Valley is to be found 3.5 miles west of Mifflintown on the south side of the valley. The section is exposed in a swine yard on the low bank of a small stream. The section is located 4,000 feet south of lat. 40° 35′ N. and 1,300 feet east of long. 77° 30′ W.

The upper contact of the Bloomsburg Formation is covered. Isolated exposures and float crop allow a relatively accurate determination of its position. The lower one-third of the Bloomsburg Formation as well as the contact with the Mifflintown Formation is also covered. It is possible to determine the position of the lower contact of the Bloomsburg Formation by detailed mapping, but because the lower one-third of the Blooms-

burg is involved in folding and thus is in part structurally repeated, an accurate determination of the thickness of the lower part is impossible. Since this section is close to the Mifflintown section (Locality 8) it is probable that the thickness is nearly equal to that section.

The Licking Creek Valley section is included in this report because it contains fossils of a rather unusual nature even for the Bloomsburg Formation. A few ostracod species normally found only in marine limestones and shales of the Upper Member of the Mifflintown Formation have been found in the red beds only at this locality. The red beds of this section also bear the only abundant Foraminifera of the Bloomsburg Formation.

Wills Creek Formation

Covered. Claystone float.

Bloomsburg Formation

Upper Member *Unit*	*Unit Thickness*	*Cumulative Thickness*
1. Covered. Grayish-red claystone float. One foot of mottled greenish-gray (5GY6/1) and grayish-red, calcareous, fossiliferous claystone 23 feet below top. Ostracoda: *Pseudobeyrichia simplex* (VR), *Kloedenia normalis* (R), *Dizygopleura halli* (VR).	66.5	66.5
Moyer Ridge Member		
2. Interbedded very-fine-grained sandstone, sandy siltstone, siltstone, grayish-red, non-calcareous. Bedding from 2 inches to 2 feet.	50	116.5
Lower Member		
3. Claystone, grayish-red, weathers hackly, calcareous. Some portions calcareous enough to lose hackly character and form beds from 2 to 4 inches. Basal 1 foot mottled yellowish-gray and grayish-red claystone. Fossiliferous 4 feet below top-Ostracoda: *Kloedenia normalis* (C), *Bolbiprimitia subaequata* (R), *Kloedenella cristata* (R), *Eukloedenella curta* (R), *Dizygopleura punctella* (C), *D. ventrisulcata* (R), *Herrmannina* sp. (R), *"Bythocypris"* sp. (VR); 30 feet below top-Brachiopoda: *Lingula* sp.; Ostracoda: *Kloedenia normalis* (VR), *Bolbiprimitia subaequata* (R), *Dizygopleura punctella* (C), *Herrmannina* sp. (R); Chordata: ?Agnathid fragments (R); 35 feet below top-Foraminifera: *Bathysiphon* cf. *B. exiguus* (C), *Lagenammina* cf. *L. cornuta* (C), *L.* cf. *L. stilla* (C), Ostracoda: *Pseudobeyrichia simplex* (VR), *Kloedenella cristata* (R),		

Unit		Unit Thickness	Cumulative Thickness
	Eukloedenella sp. (C), *Dizygopleura punctella* (C), *Herrmannina* sp. (R), *"Bythocypris"* sp. (R); Chordata: ?Agnathid fragments (R); 48 feet below top-Brachiopoda: Articulate brachiopod fragments (R), Bryozoa: gen. and sp. undet. (R); Ostracoda: *Paraechmina postica* (VR), *Velibeyrichia mesleri* (VR), *Kloedenia normalis* (C), *Kloedenella gibberosa* (C), *Eukloedenella* sp. (R), *Dizygopleura punctella* (C), *Herrmannina willsensis* (C); Crinoidea: crinoid columnals (R); Chordata: ?Agnathid fragments (VR); at base-Brachiopoda: Articulate brachiopod fragments (R); Ostracoda: *Kloedenia normalis* (R), *Kloedenella gibberosa* (R), *Eukloedenella umbilicata* (VR), *Dizygopleura gibba* (VR), *D. punctella* (R), *Herrmannina* sp. (C).	59	175.5
4.	Interbedded argillaceous limestone and very calcareous claystone, greenish-gray (5GY6/1) to dark-greenish-gray (5GY4/1). At middle 1 foot light-olive-gray (5Y6/1) and grayish-red claystone. Fossiliferous 3 feet below top-Brachiopoda: Articulate brachiopod fragments (C); Pelecypoda: gen. and sp. undet. (C); Ostracoda: *Velibeyrichia mesleri* (VR), *Kloedenia normalis* (R), *Kloedenella gibberosa* (R), *Dizygopleura gibba* (R), *Herrmannina* sp. (R).	8.5	184
5.	Claystone, grayish-red, weathers hackly, calcareous. A few inches of greenish-gray (5GY6/1) to light-olive-gray (5Y6/1) claystone at 6, 10 and 25 feet below top; 3 feet light-olive-gray (5Y6/1) to greenish-gray (5GY6/1) shale at 44 feet below top. Fossiliferous at top-Ostracoda: *Velibeyrichia tricornia* (C), *Kloedenia normalis* (C), *Kloedenella gibberosa* (C), *Dizygopleura gibba* (R), *"Bythocypris"* sp. (VR); 16 feet from top-Brachiopoda: Articulate brachiopod fragments (VR); Bryozoa: gen. and sp. undet. (VR); Ostracoda: *Velibeyrichia mesleri* (C), *Kloedenia normalis* (R), *Kyamodes? tricornis* (VR), *Kloedenella gibberosa* (C),		

Unit		Unit Thickness	Cumulative Thickness
	K. berdanae (C), *Dizygopleura perrugosa* (VR), *D. punctella* (R), *Herrmannina* sp. (VR); Tentaculoidea: *Tentaculites* sp. (R); 48 feet from top-Brachiopoda: *Lingula* sp. (VR), Articulate brachiopod fragments (R); Bryozoa: gen. and sp. undet. (R); Ostracoda: *Paraechmina inaequalis* (R), *Velibeyrichia mesleri* (VR), *Kloedenia normalis* (C), *Kloedenella gibberosa* (C), *K. berdanae* (C), *Dizygopleura gibba* (VR), *Herrmannina* sp. (R); Tentaculoidea: *Tentaculites* sp. (R).	60	244
6.	Partly covered. Claystone, grayish-red, weathers hackly with 5 feet of light-olive-gray (5Y6/1) claystone 7 and 23 feet below top.	30	274—measured

Summary. The upper 60 feet of the Bloomsburg Formation is covered. The covered interval is underlain by 50 feet of interbedded very-fine-grained sandstone and siltstone forming a minor ridge. The remaining exposed Bloomsburg Formation is mostly grayish-red, calcareous, fossiliferous claystone. The fossils are abundant, varied, and well preserved. The basal portion of the Bloomsburg Formation is covered and involved in folding. The true thickness of the section is undeterminable.

Locality 10.—Mill Hall, Pa.

The Bloomsburg Formation at Mill Hall is exposed in an abandoned brick factory quarry on the east side of Mill Hall Gap just east of the town of Mill Hall, Lock Haven quad., Clinton County, Pa. The quarry is located 8,500 feet north of lat. 41° 5′ N. and 5,300 feet east of long. 77° 30′ W.

The quarry is divided into several pits extending along strike, separated by low ridges of non-red claystone. Most of the pits are overgrown and serve as refuse dumps for the brick factory discards. The refuse covers small parts of the section. Because the pits extend several hundred feet along strike and expose the section at widely scattered places, it was possible to measure and piece together a nearly complete section of the Bloomsburg Formation.

The upper 20 feet of the Bloomsburg Formation is covered. The contact between the Wills Creek and Bloomsburg Formations is assumed to be at the top of the narrow covered interval overlying the exposed red beds, because the covered interval lies in a pit which is assumed to have originally contained red beds that were quarried out for the brick making

and because the exposures above this are all of the typical Wills Creek lithology. The basal contact of the Bloomsburg Formation is also not exposed, but the float crop below the stratigraphically lowest observed red bed is predominantly non-red and is assumed to belong to the Mifflintown Formation. The basal contact is established as the change in color from red to non-red. The Moyer Ridge Member is not separable in this section.

Wills Creek Formation

Claystone, light-olive-gray (5Y6/1) to dusky-yellow, somewhat fissile.

Bloomsburg Formation

Unit		*Unit Thickness*	*Cumulative Thickness*
1.	Covered. Brick refuse.	23	23
2.	Claystone, grayish-red, weathers hackly, 1 foot of mottled light-olive-gray (5Y6/1) to dusky-yellow claystone at base.	4	27
3.	Claystone, grayish-red, weathers hackly, calcareous, siltier near middle. Lower 40 feet partly covered. Fossiliferous 14 feet below top-Brachiopoda: *Lingula* sp. (R); Ostracoda: *Kloedenia normalis* (C), *Dizygopleura halli* (VC), *D.* ? *pulchella* (VR); 88 feet below top-Ostracoda: *Kloedenia normalis* (VR), *Eukloedenella curta* (R), *Dizygopleura punctella* (C), *Herrmannina* sp. (R).	111.5	138.5
4.	Claystone, light-olive-gray (5Y6/1), calcareous, partly fissile. Fossiliferous at middle-Ostracoda: *Kloedenia normalis* (VR), *Dizygopleura punctella* (VR), *Herrmannina* sp. (VR).	5.5	144
5.	Claystone, mottled light-olive-gray (5Y6/1) and grayish-red, very calcareous. Units 4 and 5 form low ridge in the quarry.	8.5	152.5
6.	Claystone, grayish-red, weathers hackly, calcareous, with a few 1 to 2 inches beds of greenish-gray (5GY6/1) claystone. Fossiliferous 4 feet below top-Ostracoda: *Kloedenia normalis* (VR), *Kloedenella berdanae* (R), *Eukloedenella* sp. (R); 20 feet below top-Ostracoda: *Velibeyrichia mesleri* (VR), *Kloedenia normalis* (C), *Kloedenella berdanae* (C); 36 feet below top-Ostracoda: *Kloedenia normalis* (R), *Kloedenella berdanae* (VR), *Dizygopleura punctella* (VR), *Herrmannina* sp. (R); 60 feet below top-Brachiopoda: *Lingula* sp.		

Unit		Unit Thickness	Cumulative Thickness
	(C); Ostracoda: *Pseudobeyrichia ventrilirata* (R), *Kloedenia normalis* (C), *Bolbiprimitia subaequata* (C), *Kloedenella berdanae* (C), *Eukloedenella umbilicata* (C), *Dizygopleura punctella* (R).	72	224.5
7.	Claystone, interbedded light-olive-gray (5Y6/1) and grayish-red, weathers hackly, calcareous. Fossiliferous 9 feet below top-Brachiopoda: *Lingula* sp. (R); Ostracoda: *Pseudobeyrichia ventrilirata* (C), *Kloedenia normalis* (R), *Bolbiprimitia subaequata* (R), *Dizygopleura punctella* (C).	11	235.5
8.	Claystone, grayish-red, weathers hackly, calcareous. Upper 40 feet partly covered. A few 1 to 2 inch beds of greenish-gray (5GY6/1) to light-olive-gray (5Y6/1) claystone. Fossiliferous 13 feet below top-Ostracoda: *Pseudobeyrichia ventrilirata* (R), *Kloedenia normalis* (C), *Bolbiprimitia subaequata* (C), *Eukloedenella umbilicata* (C), *Dizygopleura punctella* (C); 46 feet below top-Ostracoda: *Kloedenia normalis* (C), *Bolbiprimitia subaequata* (VR), *Kloedenella gibberosa* (R), *Dizygopleura punctella* (C); 58 feet below top-Ostracoda: *Kloedenia normalis* (R), *Eukloedenella* sp. (R), *Dizygopleura punctella* (R).	131.5	367—Total
Mifflintown Formation			
	Covered. Float dusky-yellow claystone.		

Summary. The upper contact and the upper 20 feet are covered. The remaining 350 feet of the section is predominantly grayish-red, calcareous, hackly weathering claystone with two major interbeds of olive claystone, each about 15 feet thick, 140 and 225 feet below the top. The claystone is fossiliferous at various positions; the fossils are common but not well preserved except in a few samples. The basal contact is hidden and is placed at the change in color from red to dusky-yellow.

Locality 11.—Lewistown, Pa.

The Bloomsburg section at Lewistown is exposed along the Pennsylvania Railroad on the south side of the Juniata River half a mile southeast of the Lewistown Railroad Station, Lewistown quad., Mifflin County, Pa. The section is located 500 feet north of lat. 40° 35′ N. and 2,800 feet east of long. 40° 35′ W.

Both the upper and lower contacts of the Bloomsburg Formation are

well exposed. The contact of the Bloomsburg and Wills Creek Formations is transitional. For the purposes of this paper the top of the Bloomsburg is placed at the first light-olive-gray (5Y6/1) claystone above the grayish-red sandy siltstone and very-fine-grained sandstone of the upper Bloomsburg. The basal contact is established at the base of the lowest observed red bed.

This section was briefly described by Swartz (1934, p. 94). Swartz mentions finding some ostracods, "apparently *Kloedenella gibberosa*," in green shale in the Bloomsburg, (Unit 6?).

The portion of the section which would most likely be assigned to the Moyer Ridge Member is covered at this locality and thus the position of the member cannot be accurately placed. It is possible that the lower 5 feet of unit 1 belongs to the Moyer Ridge Member.

Wills Creek Formation

Claystone, variegated, calcareous.

Bloomsburg Formation *Unit*	*Unit Thickness*	*Cumulative Thickness*
1. Claystone, grayish-red, portions calcareous, weathers hackly. Lower 5 feet sandy siltstone. Very calcareous, mottled greenish-gray (5GY6/1) and grayish-red, fossiliferous zone 4 feet from top. Brachiopoda: *Lingula* sp. (VR); Ostracoda: *Kloedenia normalis* (C), *Dizygopleura halli* (VR), *Herrmannina* sp. (C).	34.5	34.5
2. Covered. Small valley.	100	134.5
3. Claystone, grayish-red, weathers hackly, calcareous, 1 foot light-olive-gray, fissile claystone at 10 and 16 feet below top. Fossiliferous 19 feet below top-Ostracoda: *Velibeyrichia mesleri* (C), *Kloedenia normalis* (R), *Kloedenella berdanae* (C), *K. gibberosa* (VR).	23	157.5
4. Claystone, light-olive-gray (5Y5/2), fissile.	3.5	161
5. Claystone, grayish-red, weathers hackly, calcareous. Fossiliferous at top-Brachiopoda: *Lingula* sp. (VR); Ostracoda: *Kloedenia normalis* (VR), *Kloedenella gibberosa* (VR), *K. berdanae* (C), *Eukloedenella sinuata* (VR), *Dizygopleura punctella* (C), *"Bythocypris" philipsiana* (R); Chordata: ?Agnathid scales (R).	8.5	169.5
6. Claystone, light-olive-gray (5Y5/2), fissile, with a few one-half to 1 inch beds of medium-gray fossiliferous limestone. Os-		

Unit		Unit Thickness	Cumulative Thickness
	tracoda: *Kloedenia normalis* (VC), *Kloedenella gibberosa* (C), *Eukloedenella sinuata* (VR), *"Bythocypris" philipsiana* (R).	3.5	173
7.	Repeat unit 5 lithology.	6	179
8.	Claystone, greenish-gray (5GY6/1) to light-olive-gray (5Y5/2) with a few 1 to 2 inch beds of medium-gray limestone. Near top of outcrop this unit appears structurally complicated and may contain a fault of small displacement.	5	184
9.	Claystone, grayish-red, weathers hackly, portions calcareous, some thin zones somewhat fissile, a few thin zones of greenish-gray (5GY6/1). Fossiliferous 10 feet below top-Brachiopoda: *Lingula* sp. (C), Ostracoda: *Pseudobeyrichia ventrilirata* (C), *Kloedenia normalis* (C), *Eukloedenella umbilicata* (C), Chordata: ?Agnathid scales (VR): 17 feet below top-Brachiopoda: *Lingula* sp. (VR); Ostracoda: *Kloedenia normalis* (R), *Eukloedenella umbilicata* (VC), *Dizygopleura punctella* (VC), *Herrmannina* sp. (VR); Chordata: ?Agnathid scales (C); 71 feet below top-Brachiopoda: *Lingula* sp. (R); Ostracoda: *Kloedenia normalis* (C), *Dizygopleura punctella* (VR), *Herrmannina* sp. (VR); 88 feet below top-Ostracoda: *Kloedenia normalis* (VR), *Herrmannina* sp. (C).	90	274
10.	Covered.	24	298
11.	Repeat unit 5 lithology.	11	309—Total
Mifflintown Formation			
	Interbedded medium-gray limestone and shale.		

Summary. The upper contact is well exposed as is the upper 35 feet of grayish-red, silty claystone. This is underlain by 100 feet of covered interval. The remainder of the section is well exposed and consists mostly of grayish-red, calcareous, hackly weathering, fossiliferous claystone, with some interbeds of olive claystone and medium-gray limestone. Some of the fossils, especially in the limestone, are well preserved. The lower contact is exposed but obscured by foliage.

Locality 12.—Strodes Mills, Pa.

The exposure of the Bloomsburg Formation that was measured for this section description is located along the county road and in a farm

yard about 0.3 of a mile southeast of Strodes Mills, Lewistown quad., Mifflin County, Pa. The section is 12,800 feet south of lat. 40° 35′ N. and 800 feet west of long. 77° 40′ W.

The section as measured is in two parts. The upper portion of the Bloomsburg Formation (Units 1 to 5) and the contact with the Wills Creek Formation is exposed along the county road. The upper contact of the Bloomsburg Formation is established at the top of the grayish-red unit above which 13 feet of light-olive-gray (5Y5/2) and dusky-yellow claystone are exposed. The Wills Creek Formation is mostly covered above this unit. The remainder of the Bloomsburg Formation is partially exposed in a farm lane and farm yard about 200 yards northeast of the exposure on the road (Units 6 to 14). The exposure ends in the farm yard near the west end of the barn. The lower portion of the Bloomsburg and the contact with the Mifflintown Formation are not exposed, and the position of the basal contact was not determined. It is probable that only a few feet of the lower Bloomsburg is covered. This opinion is based on the fact that the thickness of the Bloomsburg at Lewistown is slightly less than the total exposed at Strodes Mills.

Swartz (1934, p. 93) described the upper 88 feet of the Bloomsburg in his Strodes Mills Section of the Tonoloway and Wills Creek Formations but did not mention the presence of fossils in the upper few feet of the Bloomsburg.

Wills Creek Formation

Claystone, light-olive-gray and dusky-yellow.

Bloomsburg Formation

Upper Member *Unit*	*Unit Thickness*	*Cumulative Thickness*
1. Claystone, grayish-red, weathers hackly, upper portion calcareous, 2 feet of greenish-gray (5GY6/1) claystone and argillaceous limestone 3 feet below top. Fossiliferous 8 feet below top-Ostracoda: *Kloedenia normalis* (C), *Dizygopleura halli* (C); Chordata: Heterostracid scales (R).	34	34
2. Covered. Driveway.	13.5	47.5
Moyer Ridge Member		
3. Siltstone, very-fine-grained sandstone and some claystone, grayish-red, lower few feet partly calcareous.	15.5	63
4. Claystone, greenish-gray (5GY6/1), partly fissile, calcareous. At base 6 to 8 inches very-fine-grained sandstone, noncalcareous, resistant.	2.5	65.5

Unit	*Unit Thickness*	*Cumulative Thickness*
5. Claystone, siltstone, and very-fine-grained sandstone, grayish-red, some weathers hackly, bedding ranges from 4 inches to 2 feet. Lower 5 feet contain calcareous nodules weathering pale red.	18.5	84
Lower Member		
6. Claystone, brownish-gray, also mottled light-olive-gray (5Y6/1) and grayish-red, calcareous. Fossiliferous at middle-Gastropoda: gen. and sp. undet. (VR); Ostracoda: *Kloedenia normalis* (VR), *Bolbiprimitia subaequata* (C), *Kloedenella cristata* (VR), *Dizygopleura punctella* (C), *D. ventrisulcata* (R), *Herrmannina* sp. (R).	3	87
7. Claystone, grayish-red, calcareous and noncalcareous, in most part poorly exposed. One foot light-olive-gray (5Y5/2) claystone at 7 and 12 feet from top. Fossiliferous 38 feet from top-Brachiopoda: Articulate brachiopod fragments (R); Ostracoda: *Kloedenia normalis* (R), *Kloedenella gibberosa* (R), *Herrmannina* sp. (R).	44	131
8. Covered. Grayish-red claystone float.	18.5	149.5
9. Claystone, interbedded pale-olive and grayish-red, lower 6 feet all pale olive. Fossiliferous 4 feet below top-Brachiopoda: Articulate brachiopod fragments (C); Ostracoda: *Velibeyrichia tricornia* (C), *Kloedenella gibberosa* (C), *Eukloedenella sinuata* (VR); Chordata: Heterostracid scales (C).	14.5	164
10. Claystone, grayish-red, weathers hackly, calcareous. Fossiliferous at middle-Brachiopoda: Articulate brachiopod fragments (C); Bryozoa: gen. and sp. undet. (VR); Ostracoda: *Velibeyrichia mesleri* (C), *Kloedenella berdanae* (C), *Herrmannina* sp. (R).	4.5	168.5
11. Covered. Mostly grayish-red claystone float with a few feet exposed. Two feet pale-olive claystones at 17 and 31 feet below top.	33.5	202
12. Repeat unit 10 lithology.	6	208
13. Interbedded claystone and limestone, light-olive-gray (5Y5/2) to medium-dark-		

Unit	Unit Thickness	Cumulative Thickness
gray, 1 foot grayish-red claystone 9 feet below top.	20	228
14. Claystone, grayish-red, weathers hackly, calcareous, upper 14 feet partly covered, 1 foot light-olive-gray (5Y5/2) claystone 9 and 24 feet below top. Fossiliferous 20 feet from top-Brachiopoda: Articulate brachiopod fragments (C); Ostracoda: *Kloedenella normalis* (VC), *Bolbiprimitia subaequata* (R), *Dizygopleura punctella* (VC); 36 feet below top-Ostracoda: *Dizygopleura punctella* (VR); Chordata: ?Agnathid scales (VR).	82	310—measured
Mifflintown Formation		
Covered.		

Summary. The upper contact and the upper 35 feet are well exposed. Below a short covered interval occur 40 feet of siltstone and very-fine-grained sandstone, mostly grayish-red, which is exposed along the road. The remainder of the section is exposed in a farm yard and consists of grayish-red and olive claystones with a small amount of limestone. The lower claystones are moderately fossiliferous. The basal portion of the Bloomsburg Formation and the contact with the Mifflintown Formation is covered. The total thickness of the Bloomsburg Formation was not determined.

Locality 13.—Pine Glen, Pa.

The section of the Bloomsburg Formation at Pine Glen is a composite one made up of exposures along the Pennsylvania Railroad 0.5 of a mile northeast of Pine Glen, and exposures along the old main highway and county road leading to the northwest from the old main highway at Pine Glen, Lewistown quad., Mifflin County, Pa. The exposure on the railroad is 3,500 feet north of lat. 40° 30′ N. and 2,800 feet west of long. 77° 40′ W. The exposure on the old main highway is 800 feet north of lat. 40° 30′ N. and 5,000 feet west of long. 77° 40′ W.

The upper part of the Bloomsburg Formation is well exposed along the railroad; the middle part is exposed along the old road. The lower Bloomsburg does not crop out well at either locality. The lower Bloomsburg can be examined best along the railroad where it is intermittently exposed.

As shown in the section, the Bloomsburg Formation of this area is divisible into two major units of red beds with an interbedded red and nonred claystone and limestone unit separating them. This red and non-

red unit represents the northeasterly extension of the Upper Member of the Mifflintown Formation which is a prominent unit at the nearby Mt. Union section. The nonred portions of the unit are not sufficiently conspicuous in the Pine Glen area to redefine and restrict the Bloomsburg Formation to the upper red bed unit as is done at Mt. Union.

The contact of the Wills Creek and Bloomsburg Formations is covered along the railroad, but only a five-foot covered interval intervenes between the stratigraphically highest Bloomsburg red bed and the lowest observed Wills Creek lithology. The basal contact is covered at both exposures but is very roughly determined along the railroad. Units 1 to 9, 21 and 22 are from the railroad exposure. Units 10 to 20 are from the exposure along the old main highway.

Wills Creek Formation

Basal 5 feet covered. Intermittently exposed above as interbedded variegated claystone.

Bloomsburg Formation

Upper Member *Unit*	*Unit Thickness*	*Cumulative Thickness*
1. Claystone, grayish-red, weathers hackly, top 4 inches light-olive-gray (5Y5/2), 1 foot from base 6 inches brownish-gray and light-olive-gray, fossiliferous claystone. Ostracoda: *Kloedenia normalis* (R), *Dizygopleura halli* (R), *Herrmannina* sp. (R); Chordata: Heterostracid scales (R).	8	8
2. Covered.	7	15
3. Claystone, grayish-red, weathers hackly, calcareous, basal foot light-olive-gray (5Y5/2), noncalcareous, somewhat fissile. Fossiliferous 5 feet from top-Brachiopoda: *Lingula* sp. (R); Ostracoda: *Kloedenia normalis* (C), *Bolbiprimitia subaequata* (VR), *Dizygopleura halli* (C), *D.* ? *pulchella* (R), *Herrmannina* sp. (R); Chordata: Heterostracid plates (R).	20	35
Moyer Ridge Member		
4. Siltstone and silty claystone, grayish-red, weathers hackly. One foot very-fine-grained sandstone 8 feet from top; 6 inches fissile, laminated, light-olive-gray (5Y5/2) claystone 13 feet below top.	28	63
5. Claystone, grayish-red, somewhat fissile, partly covered. Lower 1 foot light-olive-gray (5Y5/2) to pale olive.	6.5	69.5
6. Sandy siltstone and claystone, grayish-		

Unit	*Unit Thickness*	*Cumulative Thickness*
red, noncalcareous, lower 4 feet with calcareous nodules.	16	85.5
Lower Member		
7. Covered.	13.5	99
8. Claystone, interbedded grayish-red and grayish-olive to pale olive. Olive portions partly fissile. Fossiliferous 13 feet from top-Foraminifera: *Lagenammina* cf. *L. stilla* (C); Ostracoda: *Pseudobeyrichia simplex* (R), *Dizygopleura punctella* (C), *Herrmannina* sp. (R); Chordata: Heterostracid scales (VR).	27.5	126.5
9. Covered.	18.5	145
10. Claystone, grayish-red, bedding from 1 to 6 inches, some beds with thin brownish-gray limestone lenses. Fossiliferous at base-Ostracoda: *Velibeyrichia mesleri* (VR), *Kloedenia normalis* (R), *Kloedenella gibberosa* (C), *Herrmannina* sp. (R).	8	153
11. Claystone, light-olive-gray (5Y5/2), calcareous, fissile, with 1 to 3 inch beds of argillaceous limestone.	5.5	158.5
12. Claystone, grayish-red, weathers hackly, calcareous.	7.5	166
13. Covered. Grayish-red claystone float.	8.5	174.5
14. Claystone, pale-olive, fissile, calcareous, Fossiliferous at base-Ostracoda: *Kloedenia normalis, Kloedenella gibberosa* (C), Chordata: Heterostracid scales (R).	5	179.5
15. Repeat unit 12 lithology.	2	181.5
16. Claystone, light-olive-gray (5Y5/2), calcareous. Top 1 foot brownish-gray to greenish-gray (5GY6/1) limestone, composed mostly of broken brachiopod valves. Fossiliferous at base-Brachiopoda: Articulate brachiopod fragments (R); Bryozoan: gen. and sp. undet. (R); Pelecypoda: gen. and sp. undet. (R); Ostracoda: *Kloedenia normalis* (VR), *Kloedenella gibberosa* (C).	2.5	184
17. Claystone, grayish-red, calcareous, with very calcareous nodules arranged along bedding.	4.5	188.5
18. Claystone, light-olive-gray, slightly fissile, calcareous with interbeds of 1 to 2 inch fossiliferous and unfossiliferous medium-gray limestone. Fossiliferous 3 feet below		

Unit		Unit Thickness	Cumulative Thickness
	top-Brachiopoda: Articulate brachiopod fragments (C); Ostracoda: *Velibeyrichia mesleri* (C), *V. tricornia* (C), *Kloedenella gibberosa* (C), *K. berdanae* (VR), *Eukloedenella sinuata* (C), *Dizygopleura gibba* (R), *D. perrugosa* (VR), *"Bythocypris" philipsiana* (R).	8	196.5
19.	Repeat unit 12 lithology.	5	201.5
20.	Claystone, light-olive-gray, slightly fissile, with interbeds and nodules of medium-dark-gray limestone, some limestone fossiliferous, 1.5 feet grayish-red claystone at base. Fossiliferous 7 feet below top-Ostracoda: *Velibeyrichia mesleri* (R), *Kyamodes? tricornis* (C), *Kloedenella gibberosa* (C), *Eukloedenella sinuata* (C), *Dizygopleura gibba* (R); 21 feet below top-Brachiopoda; *Lingula* sp. (C); Ostracoda: *Kloedenia normalis* (R), *Dizygoplenra punctella* (C); Chordata: ?Agnathid scales (R).	21.5	223
21.	Covered. Grayish-red claystone float with a few feet of intermittent outcrop. Fossiliferous 26 feet below top-Ostracoda: *Dizygopleura punctella* (VR), *Eukloedenella* sp. (VR), *Herrmannina* sp. (VR).	71	294
22.	Covered. No indications of lithology. Contact with Mifflintown Formation within this unit but position undeterminable.	30?	324—Total
Mifflintown Formation			
	Covered at top. Exposed in stream. Medium-gray limestone and shale.		

Summary. Although the upper contact is covered, it is easily determined. The upper 35 feet of the section is claystone with a few fossiliferous zones. This upper unit is underlain by 50 feet of siltstone and some sandstone which forms a small ridge. The silty and sandy portion is underlain by 90 feet of mostly grayish-red claystone with some fossiliferous beds. This is underlain by 50 feet of interbedded olive and grayish-red claystones with interbeds of medium-gray limestone, some of which are fossiliferous. The lower 100 feet of the section is covered and consists of grayish-red claystone float with a few exposed fossiliferous zones; the basal contact is covered.

Locality 14.—Mt. Union, Pa.

The section at this locality is exposed along U. S. Route 22 on the north side of the Juniata River across from the town of Mt. Union, Mt.

Union quad., Mifflin County, Pennsylvania. The section is located 8,000 feet south of lat. 40° 25′ N. and 10,500 feet east of long. 77° 55′ W.

The Mt. Union section was described by Swartz (1934, pps. 85-86) from exposures along the U. S. highway and exposures near Lucy Furnace School 1½ miles north of Mt. Union. At the time Swartz measured the section, the lower portion of the Bloomsburg Formation, and the Upper and Rabble Run Members of the Mifflintown Formation were not exposed along the highway. The thickness of these units was determined by Swartz near Lucy Furnace School.

The highway excavations now expose more of the section than was available to Swartz. All of the Bloomsburg Formation is exposed. The Upper Member of the Mifflintown Formation is nearly all covered; the red beds of the Rabble Run Member are moderately well exposed.

The contact of the Bloomsburg and Wills Creek Formations is placed at the bed below which the rock is predominantly red and above which the rocks are predominantly of mixed colors. At the time the section was measured the contact was approximately marked at road level by a Pennsylvania Turnpike sign. The contact of the Bloomsburg and Mifflintown Formations is placed at the change from red beds to nonred claystones. The upper contact of the Rabble Run Member which is located in the middle of the Mifflintown Formation is covered but easily determined on the basis of float.

Wills Creek Formation

Variegated claystone, some portions fissile, calcareous.

Bloomsburg Formation

Upper Member

Unit	*Unit Thickness*	*Cumulative Thickness*
1. Claystone, interbedded grayish-red and greenish-gray (5GY6/1) to dark-greenish-gray (5GY4/1), portions calcareous, weathers hackly. Fossiliferous 5 feet below top-Ostracoda: *Kloedenia normalis* (C), *Herrmannina* sp. (R); at base-Ostracoda: *Kloedenia normalis* (C), *Bolbiprimitia subaequata* (VR), *Dizygopleura halli* (C), *D. ? pulchella* (VR); Chordata: Heterostracid scales (R).	10.5	10.5
2. Claystone, grayish-red, calcareous, weathers hackly.	4.5	15
3. Claystone, greenish-gray (5GY6/1), fissile, calcareous. Basal 6 inches mottled with grayish-red; fossiliferous. Brachi-		

Unit	*Unit Thickness*	*Cumulative Thickness*
opoda: Articulate brachiopod fragments (VR), *Lingula* sp. (VR), Ostracoda: *Kloedenia normalis* (R), *Dizygopleura halli* (R).	1.5	16.5
4. Claystone, grayish-red, weathers hackly, portions calcareous, middle 6 feet interbedded with greenish-gray claystone, basal 2 feet silty.	21.5	38
Moyer Ridge Member		
5. Siltstone and very-fine-grained sandstone, grayish-red, bedding from 2 inches to 1 foot, 2 feet calcareous, nodular claystone 1.5 feet from top.	12	50
6. Claystone, greenish-gray (5GY6/1), calcareous, fissile, with 2 inches of medium-gray limestone.	2	52
7. Siltstone, grayish-red, noncalcareous, bedding from 6 inches to 2 feet, lower portion mottled with greenish-gray (5GY6/1) and moderate-reddish-orange reduction patches.	13.5	65.5
Lower Member		
8. Claystone, grayish-red, weathers hackly, calcareous, fossiliferous, 1.5 feet greenish-gray (5GY6/1) fissile, claystone 23 feet below top. Fossiliferous 5 feet below top. Ostracoda: *Kloedenia normalis* (VR), *Dizygopleura punctella* (VR), *Herrmannina* sp. (R); 19 feet below top-Bryozoa: gen. and sp. undet.; Ostracoda: *Kloedenia normalis* (R), *Eukloedenella* sp. (C), *Dizygopleura punctella* (C), *Herrmannina* sp. (R); 26 feet below top-Foraminifera: *Lagenammina* cf. *L. stilla* (R): Bryozoa; gen. and sp. undet. (VR); Ostracoda: *Pseudobeyrichia simplex* (C), *Eukloedenella umbilicata* (C), *Dizygopleura punctella* (C), *Herrmannina* sp. (R).	40	105.5—Total
Mifflintown Formation		
Upper Member		
9. Claystone, grayish-olive to medium-gray, with interbeds of medium-gray limestone. Fossiliferous at base-Brachiopoda: Articulate brachiopod fragments (C); Bryozoa: gen. and sp. undet. (VR); Ostracoda: *Velibeyrichia mesleri* (C), *Kyamodes? tricornis* (VR), *Kloedenella gibberosa* (C), *Euk-*		

Unit	Unit Thickness	Cumulative Thickness
loedenella umbilicata (C), *Dizygopleura ventrisulcata* (VR), *D. perrugosa* (VR), *Herrmannina* sp. (VR), *"Bythocypris" philipsiana* (R); Crinoidea: crinoid columnals (R).	4	4
10. Covered. Intermittent exposure of olive-gray to medium-gray, calcareous and non-calcareous, fissile claystone with thin interbeds of medium-gray fossiliferous limestone. Fossils collected at 10 and 30 feet below top-Brachiopoda: *Stegerhyncus andrewsi* (C); Bryozoa: gen. and sp. undet. (R); Ostracoda: *Paraechmina depressa* (R), *P. inaequalis* (VR), *P. postica* (C), *Velibeyrichia mesleri* (C), *V. waldronensis* (R), *Dibolbina lobata* (R), *Kyamodes? tricornia* (C), *Kloedenella gibberosa* (C), *Eukloedenella sinuata* (C), *Dizygopleura gibba* (C), *D. perrugosa* (C), *"Bythocypris" philipsiana* (R); Crinoidea: Crinoid columnals (R), Tentaculoidea: *Tentaculites* sp. (R).	60.5	64.5—Total
Rabble Run Member		
11. Covered. Mixed grayish-red and olive-gray (5Y4/1) to medium-gray claystone float.	5.5	5.5
12. Claystone, grayish-red, calcareous, weathers hackly, a few inches of greenish-gray (5GY6/1) claystone at top and at a few horizons within unit, portions partly covered. Fossiliferous at top-Ostracoda: *Pseudobeyrichia* sp. (R), *Kloedenia normalis* (C), *Eukloedenella* sp. (R), *Dizygopleura punctella* (C); 15 feet below top-*Pseudobeyrichia ventrilirata* (VR), *Kloedenia normalis* (C), *Kloedenella gibberosa* (C), *Dizygopleura punctella* (C); Chordata: ?Agnathid scales (C); 30 feet below top-Brachiopoda: *Lingula* sp. (R); Bryozoa: gen. and sp. undet. (R); Ostracoda: *Kloedenia normalis* (R), *Kloedenella gibberosa* (VR), *Herrmannina* sp. (VR); Chordata: ?Agnathid scales (VR); 47 feet below top-Ostracoda: *Kloedenia normalis* (C), *Eukloedenella* sp. (R); 60 feet below top-Ostracoda: *Kloedenia normalis* (C), *Kloedenella gibberosa* (R), *Eukloedenella*		

Unit	Unit Thickness	Cumulative Thickness
umbilicata (R).	66.5	72
13. Claystone, interbedded medium-gray, fissile, and yellowish-gray, non-fissile, with a few thin interbeds of medium-gray limestone.	11	83
14. Claystone, pale-red (10R6/2), noncalcareous.	9	92
15. Covered across gully. Exposed on slope above. Claystone, grayish-red, weathers hackly.	8	100—Total
Middle Member		
Interbedded olive and gray shales and gray limestone.		

Summary. The Bloomsburg Formation and its upper and lower contacts are well exposed. The Bloomsburg Formation is mostly grayish-red claystone with a few feet of siltstone and very-fine-grained sandstone near the top. The upper and lower portions of the formation are fossiliferous. The Bloomsburg is underlain by 65 fect of gray shales and limestones of the Upper Member of the Mifflintown Formation. The upper member is underlain by 100 feet of grayish-red claystone (Rabble Run Member) with some fossiliferous zones.

Locality 15.—Neffs Mills, Pa.

In the general region of Neffs Mills, Allensville quad., Huntingdon County, are scveral exposures of the Bloomsburg Formation and the Rabble Run Member of the Mifflintown Formation. No outcrop was found that exposed the Upper Member of the Mifflintown Formation. In order to examine most of the red beds of the Bloomsburg Formation and Rabblc Run Member in this area it was necessary to measure three outcrops.

The Bloomsburg Formation was examined in two separate exposures southeast of Neffs Mills which complement and partly duplicate each other. The exposure from which units 1 to 4 are described is located in a small borrow pit 1 mile south of Neffs Mills on Route 305. It is 13,500 feet south of lat. 40° 40′ N. and 8,500 feet west of long. 77° 55′ W. The Bloomsburg exposure at which units 5 to 9 were measured is on Route 305 in a road cut 0.9 of a mile southeast of the first outcrop and 0.7 of a mile northwest of Manor Hill. The exposure is 15,500 feet south of lat. 40° 40′ N. and 4,500 feet west of long. 77° 55′ W. The contact of the Wills Creek and Bloomsburg Formations can be seen at both localities although it is better at the first exposurc. The contact of the Bloomsburg

and Mifflintown Formations is covered and can only be estimated on the basis of float crop.

The Rabble Run Member of the Mifflintown Formation is exposed 1.4 miles south of Neffs Mills along a county road that leads to Myton School. The outcrop is 17,400 feet south of lat. 40° 40′ N. and 9,900 feet west of long. 77° 55′ W. The contact of the Upper Member and the Rabble Run Member of the Mifflintown Formation is not exposed but is determined by the change in color from red to nonred in the covered interval above the exposed portion of the Rabble Run. The basal contact of the Rabble Run Member and a few feet of the upper portion of the Lower Member are exposed.

	Unit Thickness	*Cumulative Thickness*
Wills Creek Formation		
Claystone and limestone, light-olive-gray (5Y6/1) to medium-dark-gray.		
Bloomsburg Formation		
Upper Member		
Unit		
1. Claystone, grayish-red, calcareous, weathers hackly. Fossiliferous 5 feet below top-Brachiopoda: *Lingula* sp. (R); Ostracoda: *Kloedenia normalis* (R), *Dizygopleura halli* (R), *D.* ? *pulchella* (R); Chordata: Heterostracid scales. (C).	42	42
Moyer Ridge Member		
2. Sandy siltstone, grayish-red, bedding from 2 inches to 1 foot.	6	48
3. Repeat unit 1 lithology.	3	51
4. Claystone, light-olive-gray (5Y6/1) to medium-gray, somewhat fissile, with a few interbeds of medium-gray limestone.	7	58
5. Sandy siltstone, grayish-red, lower 2 feet claystone.	10.5	68.5
Lower Member		
6. Covered.	2	70.5
7. Limestone, brownish-gray, argillaceous.	1	71.5
8. Covered. Mixed grayish-red and light-olive-gray (5Y6/1) claystone float. Base of Bloomsburg Formation not observed. Thickness estimated.	10	81.5—Total
Mifflintown Formation		
Upper Member		
9. Covered. Member not exposed and thickness undeterminable on present data.		
Rabble Run Member		
10. Claystone, grayish-red, calcareous, weathers hackly, upper portion partly covered. Fossiliferous 12 feet below top-Os-		

Unit	*Unit Thickness*	*Cumulative Thickness*
tracoda: *Kloedenia normalis* (VR), *Kloedenella gibberosa* (R), *"Bythocypris"* sp. (R); Chordata: ?Agnathid scales (R).	14.5	14.5
11. Claystone, light-olive-gray (5Y5/2), calcareous, a few thin beds very limy. Fossiliferous 1 foot from top-Ostracoda: *Kloedenia normalis* (C), *Eukloedenella umbilicata* (C).	5.5	20
12. Claystone, grayish-red, weathers hackly, calcareous, lower 8 feet partly covered with 1 foot light-olive-gray (5Y5/2) claystone near middle. Fossiliferous 17 feet below top-Ostracoda: *Kloedenia normalis* (R), *Kloedenella gibberosa* (C), *Herrmannina* sp. (R), 26 feet below top-Brachiopoda: *Lingula* sp. (R); Ostracoda: *Kloedenia normalis* (C), *"Bythocypris" philipsiana* (C); Chordata: ?Agnathid scales (R).	34	54
13. Claystone, light-olive-gray (5Y5/2), calcareous, weathers hackly.	5	59
14. Claystone, grayish-red, weathers hackly, calcareous, with some thin interbeds of light-olive-gray (5Y5/2). Fossiliferous 7 feet below top-Ostracoda: *Kloedenia normalis* (C).	10	69—Total
Middle Member		
Claystone, light-olive-gray (5Y6/1) to medium-gray, fissile, with some thin interbeds of medium-dark-gray limestone.		

Summary. The Bloomsburg Formation is mostly grayish-red claystone with about 25 feet of sandy siltstone (Moyer Ridge Member) near the middle. The upper portion of the formation is poorly fossiliferous. The upper contact is exposed, but the basal contact is not visible. The underlying upper member of the Mifflintown Formation is completely covered and its thickness is indeterminable. The Rabble Run Member below this is mostly grayish-red claystone with a few fossiliferous zones which contain poorly preserved fossils. The basal contact of the Rabble Run Member is exposed.

Locality 16.—Hollidaysburg, Pa.

At Hollidaysburg, the Bloomsburg Formation and the Upper and Rabble Run Members of the Mifflintown Formation are well exposed. The outcrop is in a borrow pit located 300 feet north of the intersection

of U. S. Route 22 and Bypass U. S. Route 22 at the east end of Hollidaysburg, Hollidaysburg quad., Blair County. The exposure is 6,500 feet north of lat. 40° 25′ N. and 1,300 feet east of long. 78° 25′ W.

This section has been exposed by a stripping operation for top soil and fill. Most of the exposure is on the borrow pit floor; there has been little excavation to any depth. At the time the section was measured the rock was little weathered and well exposed. Some of the fossils from the shales weather free and may be easily collected.

At this locality the lithologic units assigned to the Bloomsburg Formation may not truly answer the criteria of a formation. They are called a formation in this section description because they were listed in the Hollidaysburg-Huntingdon Folio (Butts, 1945) as a formation. At the Hollidaysburg exposure the Bloomsburg red beds perhaps could be ranked as a member of the Wills Creek Formation. At a nearby outcrop of the Bloomsburg Formation 1.6 miles northeast of Canoe Creek along U. S. Route 22 and 7.6 miles northeast of the described section, the red beds make up about 60% of the outcrop while at the described section the red beds amount to only about 35% of the thickness assigned to the Bloomsburg Formation. This indicates a moderate local variation in the amount of red beds present in the Bloomsburg Formation.

The Moyer Ridge Member of the Bloomsburg Formation is not separable from the other red beds at this locality. The typical sandstone and siltstone of this member apparently did not spread this far west and are here represented by claystones.

The contacts of the units described in the section are well exposed.

Wills Creek Formation

Claystone, light-olive-gray (5Y5/2) to medium-gray, fissile, calcareous, with a few thin beds of comminuted fossiliferous limestone.

Bloomsburg Formation *Unit*	*Unit Thickness*	*Cumulative Thickness*
1. Claystone, grayish-red, calcareous.	3.5	3.5
2. Claystone, light-olive-gray (5Y5/2), middle portion very calcareous, weathering dusky yellow.	17	20.5
3. Claystone, grayish-red, calcareous, somewhat fissile.	18	38.5
4. Claystone, light-olive-gray (5Y5/2), fissile, with interbeds of medium-dark-gray unfossiliferous limestone.	14.5	53
5. Claystone, light-brownish-gray, grayish-red, and light-olive-gray (5Y5/2), top foot very calcareous, lower 3 feet fissile.	4.5	57.5

Unit	*Unit Thickness*	*Cumulative Thickness*
6. Claystone, light-olive-gray (5Y5/2), fissile, with interbeds of medium-dark-gray unfossiliferous limestone, basal foot grayish-red claystone.	18	75.5—Total
Mifflintown Formation		
Upper Member		
7. Claystone, light-olive-gray (5Y5/2), calcareous, fissile, with interbeds of medium-dark-gray fossiliferous and unfossiliferous limestone. At 97 feet and 115.5 feet below top are beds of "fossil ore," fossiliferous limestone in part replaced by hematite. Fossiliferous 30 feet below top-Coelenterata: *Favosites* cf. *F. niagarensis* (C), Bryozoa: gen. and sp. undet. (R); Brachiopoda: *Stegerhynchus andrewsi* (C); Pelecypoda: *Leiopteria* sp. (C); Ostracoda: *Paraechmina postica* (R), *P. depressa* (R), *Velibeyrichia mesleri* (C), *V. waldronensis* (R), *Dibolbina lobata* (R), *Kyamodes? tricornis* (C), *Kloedenella gibberosa* (VC), *Eukloedenella sinuata* (VC), *Dizygopleura gibba* (VC), *D. perrugosa* (C), *"Bythocypris" philipsiana* (VC); Annelida?: *Cornulites* sp. (R); 59 and 74 feet below top-Coelenterata: *Favosites* cf. *F. niagarensis* (R); Brachiopoda: *Stegerhynchus andrewsi* (C); Pelecypoda: *Leiopteria* sp. (R), Ostracoda: *Paraechmina postica* (R), *P. depressa* (VR), *P. inaequalis* (VR), *Velibeyrichia mesleri* (C), *V. waldronensis* (R), *V. tricornia* (VC), *Dibolbina lobata* (VR), *Kyamodes? tricornis* (C), *Kloedenella gibberosa* (VC), *Eukloedenella sinuata* (C), *Dizygopleura gibba* (C), *D. perrugosa* (C), *"Bythocypris" philipsiana* (VC); Tentaculoidea: *Tentaculites* sp. (R); 107 feet below top-Ostracoda: *Pseudobeyrichia ventrilirata* (VR), *Kloedenia normalis* (VR), *Kloedenella gibberosa* (C), *Eukloedenella umbilicata* (R), *Dizygopleura unipunctata* (VR).	122.5	122.5—Total
Rabble Run Member		
8. Claystone, light-olive-gray (5Y5/2), calcareous, fissile, with thin interbeds of medium-dark-gray fossiliferous and unfossiliferous limestone, top 1.5 feet and basal		

Unit	Unit Thickness	Cumulative Thickness
2 feet grayish-red claystone. Fossiliferous 13 feet below top-Ostracoda: *Pseudobeyrichia ventrilirata* (C), *Kloedenia normalis* (VC), *Kloedenella gibberosa* (C), *Eukloedenella umbilicata* (C), *Herrmannina* sp. (R), *"Bythocypris"* sp. (R).	21.5	21.5
9. Claystone, light-olive-gray (5Y5/2), calcareous, fissile, with some limestone interbeds. Fossiliferous 3 feet below top-Ostracoda: *Pseudobeyrichia ventrilirata* (VC), *Dibolbina lobata* (VR), *Kloedenia normalis* (C), *Kloedenella gibberosa* (VC), *Eukloedenella umbilicata* (VC), *Dizygopleura gibba* (VR).	5.5	27
10. Interbedded grayish-red and light-olive-gray (5Y5/2) claystone, with a few thin interbeds of medium-dark-gray unfossiliferous limestone.	24	51—Total
Middle Member		
Claystone, light-olive-gray (5Y5/2) and thin interbeds of limestone. Top taken at base of lowest observed red bed.		

Summary. The Bloomsburg Formation is interbedded grayish-red and light-olive-gray (5Y5/2) claystone with the red beds in minority. The upper member of the Mifflintown Formation is interbedded gray claystone and limestone, many beds of which are very fossiliferous with very well preserved fossils. The Rabble Run Member of the Mifflintown Formation is interbedded grayish-red and olive claystones with a few thin limestone interbeds. Some of the red beds are fossiliferous.

Locality 17.—Bedford, Pa.

To obtain a complete section of the stratigraphic interval that includes the Bloomsburg and Rabble Run red beds in the Bedford area, it was necessary to measure two exposures. The first exposure is along a small stream that passes through the Ritchey farm 2 miles southwest of Bedford on the west side of U. S. Route 220. The section is 0 feet south of lat. 40° N. and 9,500 feet west of long. 78° 30′ W. in the Hyndman quad., Bedford County, Pa. The second exposure which includes the upper two members of the Mifflintown Formation is located on the north side of the Pennsylvania Turnpike about 500 feet west of the Bedford Interchange in the Bedford quad., Bedford County. The exposure is located 11,800 feet south of lat. 40° 05′ N. and 5,000 feet west of long. 78° 30′ W.

In this area the red beds that are assigned to the Bloomsburg are thin and are predominantly made up of the Moyer Ridge Member. Both the upper and lower contacts of the Bloomsburg are present at the Ritchey Farm exposure. The contact of the Mifflintown Formation with the Bloomsburg Formation is not visible at the Turnpike exposure but is placed immediately above the exposed section on the basis of Bloomsburg outcrop in the farm field about 20 yards north of the exposure. The red beds belonging to the Rabble Run Member of the Mifflintown Formation are also thin. At a poor outcrop 1.5 miles south of St. Clairsville and 5.9 miles north of the Turnpike exposure the Rabble Run is again exposed. Here the unit is about 50 feet thick with red beds constituting two-thirds of the section. At the Turnpike exposure the red beds make up one-quarter of the Rabble Run thickness. This indicates a moderate local variation in amount of red beds in the Rabble Run Member in the general Bedford region.

Wills Creek Formation

Interbedded claystone, medium-light-gray to light-olive-gray (5Y6/1), and medium-gray limestone.

Bloomsburg Formation

Unit	*Unit Thickness*	*Cumulative Thickness*
Upper Member		
1. Claystone, grayish-red, weathers hackly, calcareous, with 2 feet light-olive-gray (5Y6/1), claystone 6 feet below top.	10.5	10.5
2. Claystone, medium-gray to light-olive-gray (5Y6/1), weathers hackly, partly fissile.	4	14.5
Moyer Ridge Member		
3. Siltstone, sandy, grayish-red with some very-fine-grained sandstone, bedding from 2 to 6 inches.	9	23.5
4. Covered.	7.5	31
5. Sandstone, very-fine-grained, silty, grayish-red grading to medium-gray, resistant.	4.5	35.5
Lower Member		
6. Claystone, grayish-red, weathers hackly, calcareous with 1 foot light-olive-gray (5Y6/1), noncalcareous claystone at top.	7.5	43—Total

Mifflintown Formation

Upper Member

7. Interbedded claystone, light-olive-gray (5Y6/1) to medium-gray, fissile, and medium-gray, fossiliferous limestone. Limestone beds from one-half to 4 inches. Fossiliferous 1 foot below top-Ostracoda: *Kloedenella gibberosa* (C), *K. cristata*

Unit	Unit Thickness	Cumulative Thickness
(R), *Eukloedenella umbilicata* (C), *Dizygopleura swartzi* (VR), *D. unipunctata* (VR); 13 feet below top-Ostracoda: *Kloedenella gibberosa* (VC), *K. cristata* (R), *Eukloedenella umbilicata* (VC), *Dizygopleura swartzi* (C), *D. unipunctata* (C); 31 feet below top-Ostracoda: *Velibeyrichia mesleri* (VR), *V. waldronensis* (R), *Kloedenella gibberosa* (VC), *Eukloedenella umbilicata* (C), *Dizygopleura unipunctata* (R), *D. punctella* (VR); Tentaculoidea: *Tentaculites* sp. (R); 49 feet below top-Brachiopoda: Articulate brachiopod fragments (VC); Ostracoda: *Paraechmina postica* (VR); *P. inaequalis* (VR), *Velibeyrichia tricornia* (C), *Kloedenella gibberosa* (C), *Dizygopleura gibba* (R).	72	72—Total
Rabble Run Member		
8. Claystone, grayish-red, calcareous, weathers hackly. Fossiliferous 1 foot from top-Ostracoda: *Kloedenia normalis* (R), *Kloedenella gibberosa* (C), *Eukloedenella umbilicata* (R); Chordata: ?Agnathid scales (R).	3	3
9. Repeat lithology unit 7. Fossiliferous 7 feet below top-Ostracoda: *Velibeyrichia tricornia* (R), *Kloedenia normalis* (VR), *Kyamodes? tricornis* (R), *Kloedenella gibberosa* (VC), *Eukloedenella umbilicata* (C), *E. sinuata* (R), *Dizygopleura gibba* (R); 23 feet below top-Ostracoda: *Kloedenia normalis* (VR), *Kloedenella gibberosa* (VC), *Eukloedenella umbilicata* (VC).	30	33
10. Repeat lithology unit 8.	7	40—Total
Middle Member		
Interbedded olive and gray claystone and limestone, poorly exposed.		

Summary. The Bloomsburg red beds are thin, unfossiliferous claystone with a few feet of very-fine-grained sandstone. The upper member of the Mifflintown Formation is interbedded grayish and olive claystones and limestones, some of which are very fossiliferous. The Rabble Run Member is thin, and is only about one-quarter red beds, with a few fossiliferous zones in both the red and nonred.

Locality 18.—Cedar Cliff, Md.

The Williamsport Member (=Bloomsburg Member of Swartz, 1923, p. 130) of the Wills Creek Formation is well exposed along the Baltimore

and Ohio Railroad in a high cut 4 miles southwest of Cumberland, Md., at Cedar Cliff, Frostburg quad., Allegany County. This section is located 9,150 feet north of lat. 39° 35′ N. and 7,900 feet east of long. 69° 50′ W.

This section was measured by W. A. Price and was described by C. K. Swartz in the Maryland Silurian Volume (1923, p. 130). This section and the following two sections are important because they include units which are called the Cedar Cliff Limestone. Until the present study the only fossil reported from the Cedar Cliff Limestone was *"Leperditia alta."* Investigation of these sections revealed that other fossils are present in the Cedar Cliff Limestone.

The section as described by Swartz (1923, p. 130) is reproduced here with the addition of the new fossil data in parentheses.

	"Thickness	
	Beds	Total
	Feet	Feet"
Wills Creek Formation		
"Bloomsburg Member"		
"Massive, brownish-red sandstone.	2.0	23.2
Cedar Cliff Limestone consisting of:		
Thin-bedded limestone and dark calcareous shale with a few thin beds of sandstone.	3.3	21.2
Thick-bedded, bluish-gray arenaceous limestone. *Leperditia alta* occurs about 6 feet above the base of unit. [Fossiliferous near middle-Brachiopoda: Articulate brachiopod fragments (R); Ostracoda: *Kloedenia normalis* (R), *Dizygopleura halli* (VC)].	4.5	17.9
Spring.		
Light-gray calcareous shales and thin-bedded calcareous sandstone containing *Leperditia alta* near base. [Fossiliferous at base-Brachiopoda: Articulate brachiopod fragments (R); Gastropoda: gen. and sp. undet. (R); Ostracoda: *Kloedenia normalis* (R), *Kloedenella* sp. (R), *Dizygopleura halli* (C), *Herrmannina* sp. (VC)].	1.9	13.4
Thin-bedded, dark-gray calcareous sandstone containing numerous *Leperditia alta* near base.	0.5	11.5
Light-gray arenaceous limestone conglomerate, consisting of hard siliceous nodules in a softer matrix.	3.0	11.0
Massive, red sandstone.	3.0	8.0
Gray sandstone with some shale partings.	5.0	5.0"
Mifflintown Formation		
Medium-gray fissile claystone with some thin medium-dark-gray limestone.		

Locality 19.—Pinto, Md.

The excellent exposure of Silurian rocks at Pinto, Md., which is described by Swartz (1923, p. 126) includes the units belonging to the Williamsport Member of the Wills Creek Formation (= Bloomsburg Sandstone Member of Swartz). The section is along the Baltimore and Ohio Railroad cut at Pinto, Frostburg quad., Allegany County, 8 miles southwest of Cumberland, Md. The section is located 6,500 feet south of lat. 39° 35′ N. and 500 feet east of long. 69° 50′ W.

The description of the section by Swartz is adequate, and the units may still be discerned; therefore, the section is reproduced here with the addition of the new data on the fossils enclosed in parentheses.

Wills Creek Formation	"Thickness	
	Beds	Total
"Bloomsburg Sandstone Member"	Feet Inches	Feet Inches"
"Greenish, arenaceous shale, overlain by argillaceous sandstone with mud cracks on surface of the shale. Indistinct worm borings occur in the shale parallel to the bedding. About 1 foot above base occurs *Leperditia alta.*	1 8	20 8
Single course of massive, reddish-brown, highly ferruginous sandstone.	2 0	19 0
Arenaceous shale penetrated by worm borings ½ inch in diameter placed at right angles to the bedding planes.	1 0	17 0
Platy argillaceous limestone with some interbedded shale. A bed of sandstone 14 inches thick 3 feet 6 inches above the base. Middle beds are disintegrated and appear as ferruginous clay containing *Leperditia alta* in lower three feet. *The Cedar Cliff Sandstone* [Sic.]. [Fossiliferous at base-Ostracoda: *Kloedenia normalis* (R), *Bolbiprimitia subaequata* (VR), *Dizygopleura halli* (C), *D. ? pulchella* (R), *Herrmannina willsensis* (C)].	8 0	16 0
Massive, fine-grained sandstone of greenish-yellow tone.	8 0	8 0"
Mifflintown Formation		
Claystone, fissile, gray to olive.		

Locality 20.—Keyser, W. Va.

The Williamsport Member of the Wills Creek Formation is exposed three-quarters of a mile east of Keyser in a deep road cut on W. Va. Route 46. The outcrop is located 6,850 feet north of lat. 39° 25′ N. and

11,600 feet east of long. 79° W., in Keyser Quad., Mineral County.

This section is similar to and located only about half a mile north of the section described by Swartz (1923, p. 111) along the old Keyser-Heddenville Road. Relatively new road work has revealed a small exposure of Silurian strata that fortunately includes the units assigned to the Williamsport Member.

Wills Creek Formation

Claystone, variegated, portions calcareous and fissile.

Williamsport Member *Unit*	*Unit Thickness*	*Cumulative Thickness*
1. Sandstone, very-fine-grained, silty, light-olive-gray (5Y5/2).	2	2
2. Interbedded siltstone and claystone, light-olive-gray (5Y5/2), claystone fissile.	3	5
3. Limestone, shaly, dark-gray to medium-dark-gray. Fossiliferous-Ostracoda: *Kloedenia normalis* (C), *Dizygopleura halli* (C), *D. ventrisulcata* (VR), *Herrmannina* sp. (C).	2	7
4. Covered. Very weathered zone. May be equivalent of disintegrated unit at Locality 19.	6	13
5. Claystone, light-olive-gray (5Y5/2), weathers hackly.	6	19
6. Claystone, grayish-red, in one bed.	1.5	20.5
7. Sandstone, very-fine-grained, silty, light-olive-gray (5Y5/2). Top 8 inches grayish-red grading down to other color. Resistant. Base of unit and member placed at change from nonfissile to fissile.	6.5	27—Total

PALEONTOLOGY

General Statement

Among the fossils in the Bloomsburg Formation are representatives of all the major invertebrate phyla except the Phylum Porifera. For a series of red beds that heretofore were considered nearly barren this is somewhat unusual. Although all these phyla are represented at one or more places in the outcrop belt of the Bloomsburg Formation, it is estimated that 95% of the fossils belong to one phylum, the Phylum Arthropoda, and all of these arthropods belong to the Order Ostracoda. Quantitatively, the Bloomsburg Formation must be considered a fairly fossiliferous unit, although not nearly as much so as the marine sediments with which it is correlative.

Historical background

Before the present work the Bloomsburg was considered nearly barren of fossils. I. C. White (1883, p. 107), who named the Bloomsburg, found only one fossil, *Lingula,* in the whole general area in which he defined the formation. Claypole (1885, p. 51) stated that the "Bloomsburg Red Shale is almost barren. Only in one or two places has it yielded any fossils. . . . *Beyrichia notata* Hall [probably a *Kloedenia normalis*] and *Leperditia alta* Conrad." The conclusion of the other writers (see STRATIGRAPHY—*Historical Background*) who have examined the Bloomsburg Formation is that fossils are almost completely absent. All of these reports, except one, deal with portions of the Bloomsburg outside of its most fossiliferous area. Therefore, it is not surprising that the few fossiliferous beds present were overlooked. Further, most major red bed units, for example the Triassic red beds of the eastern U. S., have been found to be largely unfossiliferous. This generalization may have been applied to the Bloomsburg and led those examining the red beds to overlook them as fossiliferous units.

Tilton (1927, p. 59) lists 20 species of fossils purportedly from the Bloomsburg Formation of West Virginia. This list is unusual in that it is the first citation of a large number of fossils from the Bloomsburg red beds. The list is given below:

"Fossils of the Bloomsburg Sandstone

Lingula	*
Homeospira evax var. *marylandica* Prouty	
Tetrameroceras cumberlandicum Swartz	
Leperditia alta Jones	
Leperditia alta var. *brevicula* Ulrich and Bassler	
Leperditia elongata Weller	
Leperditia altoides var. *marylandica*	
Ctenobolbina (?) *dubia* Ulrich and Bassler	
Bollia pulchella U. and B.	*
Bollia immersa U. and B.	
Bollia nitida U. and B.	
Halliella subaequata U. and B.	*
Zygobeyrichia incipiens U. and B.	
Zygobeyrichia ventricornis U. and B.	*
Eukloedenella umbilicata curta U. and B.	*
Dizygopleura unipunctata U. and B.	
Kloedenia normalis U. and B.	*
Kloedenia kenziensis U. and B.	

Kloedenia obscura U. and B.
Bythocypris pergracilis U. and B." *

(*—present in the Bloomsburg Formation in Pennsylvania)

Woodward (1941, p. 156) suggests that this fauna was not collected from the Bloomsburg Formation. Tilton does not give the locality or any other information as to the exact origin of the specimens. Re-examination of the area in Hampshire county where Tilton must have found the fauna revealed no fossils to the writer.

More direct evidence as to the true position of this fauna is to be found in the fossils themselves. In over-all view the Hampshire county fauna is similar to the one found in the upper Bloomsburg of central Pennsylvania. Seven of the species listed by Tilton are found in the Bloomsburg of Pennsylvania. However, missing from the Hampshire county fauna is *Dizygopleura halli,* one of the persistent forms of the upper Bloomsburg and the Wills Creek Formations of Pennsylvania and Maryland.

It is entirely possible that this fauna was collected from the upper Bloomsburg of Hampshire county. It is also possible that the fossils came from a red unit in the Wills Creek that was misidentified as Bloomsburg. Because the lithology of the Bloomsburg in Hampshire county is more clastic than is usual for the fossiliferous red beds as observed in central Pennsylvania, it is the writer's opinion that the latter possibility is more likely.

The beginning of the present study was noted in Hoskins and Conlin (1958, pps. 156-161). The most recent paper dealing with Bloomsburg fossils is that of Beerbower and Hait (1959, pps. 198-203) in which they cite five new localities in Pennsylvania and New Jersey from which fossil fish (*Archegonaspis van ingeni*) have been collected. Material similar to that of Beerbower and Hait has been collected from a few other localities.

Fossiliferous localities

Forty-nine exposures of the Bloomsburg Formation or the Rabble Run Member of the Mifflintown Formation or both were visited and examined in detail for fossils; 32 of these localities contain fossils. Fossil abundance at these localities ranges from poorly fossiliferous to very fossiliferous. Two of the 32 localities are in the region where the red beds of the Bloomsburg Formation and the Rabble Run Member of the Mifflintown Formation are very thin. Thus, these sections contain mostly marine limestones and shales of the upper member of the Mifflintown Formation. The fossils at these two localities provide a marine fauna for comparative purposes from the same stratigraphic position that is occupied by red beds in the region where the Bloomsburg Formation coalesces with the Rabble Run Member.

In order to prevent needless expansion of this report, sections that were barren are not recorded. Fifteen of the fossiliferous exposures are also not described, because either the section exposed only a very small portion of the total thickness of the red beds section or it duplicated a nearby, more representative section of the local area. Most of these fifteen sections were poorly fossiliferous.

Five localities where the Williamsport Member of the Wills Creek Formation is exposed were examined; three of these exposures are described because they supplied fossils from the Cedar Cliff Limestone Lentil.

Lithologic association and preservation

The fossils in the red beds come only from the claystone and are usually found in discrete beds separated by relatively barren zones. The fossiliferous portions of the sections are somewhat more calcareous than the nonfossiliferous rock and do not generally exhibit the characteristic hackly weathering of the average claystone. With one exception fossils were not observed in the siltstone or coarser material (Figure 5). The interbedded olive and greenish-gray claystones are more frequently unfossiliferous, although many beds of this lithology are more calcareous than the grayish-red claystone.

The genera *Dizygopleura, Kloedenella,* and *Eukloedenella* are most often found as complete carapaces; the other genera usually are found as separate valves. Many of the fossils exhibit varying amounts of wear, probably from current movement prior to burial. As compared to fossils found in limestone the preservation of the fossils from the claystones is fair to very poor, but most of the specimens are sufficiently well preserved to permit easy identification. Much of the fossil shell material is partly replaced by hematite and the fossils are filled with clay or calcite and colored to match the sediment. Thus, most of the ostracod carapaces are grayish-red.

Ostracod instars

Some of the samples of shale and limestone from the upper member of the Mifflintown Formation contain specimens which apparently represent all the growth stages of certain species. One of these species is *Eukloedenella umbilicata* Ulrich and Bassler. Measurements were made on 88 male and 22 female carapaces of this species. These measurements were plotted on log-log graph paper after the manner suggested by Kesling (1953). The plotted points grouped into 10 areas, with the female carapaces grouped around the adult instar area. Thus it would appear that *E. umbilicata* has 9 instars below the adult and that sexual dimorphism appears in the last instar. This agrees with Adamczak (1959) who noted

that the ontogeny of an ostracod species terminates with the appearance of the secondary sexual characters.

One red bed sample from the Bloomsburg Formation which contained abundant ostracods was selected and from this sample 108 male carapaces of *Dizygopleura halli* (Jones) were measured and plotted as above. The plotted points grouped into two areas with about 75% of the points in the adult or last instar area. None of the earlier instars of this species were found. This is good evidence that the adult forms were not buried where they lived. Examination of all the other red bed samples revealed none with species represented by more than one or two instars below the adult.

Preparation

The most effective method of extracting the fossils from the claystone is by crushing in a crusher in which fine particles drop out so that they do not continually undergo breakage. Destruction is high, but most samples contain sufficient numbers of fossils so that many complete carapaces or individual valves are recovered. Approximately 100 grams of claystone were crushed for each sample.

Several thousand specimens were obtained from the many crushed samples. The maximum amount obtained from one sample was approximately 750 specimens. In most instances very few species are found in samples from the red beds but the few species are represented by many individuals; the reverse is partly true of the marine limestone samples.

No attempt was made to apply any statistical basis for the estimation of the frequency of the various species. The frequency notation following species names in the STRATIGRAPHIC SECTIONS are based on the writer's estimation after examination of both the crushed material and hand specimens from each sample.

Of the 268 samples collected 20 were limestone which were examined in hand sample, approximately 200 were claystone which were crushed and picked, the remaining were claystone samples which were examined in hand sample only because it was felt that they contained too few fossils to warrant crushing.

Prior to photographing, the specimens were coated with ammonium chloride in order to whiten them. All of the photographs on the plates are unretouched except for the photographs of ostracods on rock specimens and the photographs of the mounted type specimens borrowed from the U. S. National Museum; portions of the background of these photographs were inked out.

Some of the specimens from the Bloomsburg and Mifflintown Formations are very fragile and exhibit a rough or unclean surface. Attempts

to clean the surfaces of many of these fossils resulted in their destruction; therefore, many specimens whose surfaces were not perfectly clean were photographed. It is felt that this does not detract too seriously from the photographs.

Disposition of types

The holotype and paratype specimens of the new species described in this paper are to be deposited with the U. S. National Museum in Washington, D. C. The USNM before the type number is the abbreviation for the U. S. National Museum.

Orientation and terminology

The orientation and terminology for the ostracods is mainly from Kesling (1951). Some of the terms suggested by Henningsmoen (1953, 1954) are also used. In addition two terms were created to facilitate description of some species.

Some of the species of *Kloedenella* possess a small dorsal projection on the right valve that is somewhat triangular in shape. It generally lies above S_2 and may be connected by a low crest with L_3. This projection is called the dorsal protuberance and is to be distinguished from a similar dorsal structure in the genus *Eukloedenella* called the hump. The hump is a low swelling or extension of L_3 above the hinge line in both valves. It does not extend to the area over S_2 and is a much less pronounced feature than the dorsal protuberance.

Described fossils

The writer has not described fossils which are restricted to the upper member of the Mifflintown Formation, with the exception of the ostracods. Of the described fossils only the foraminifers, ostracods and fish scales are figured. The fossils of the other taxa are mostly poorly preserved and provide no useful information by being included in the plates.

Other fossils

Conversation and correspondence with Dr. Eugene Richardson, Jr. of the Chicago Natural History Museum have revealed that eurypterids also have been found in the Bloomsburg Formation. These fossils were collected by Dr. R. H. Denison from the Bloomsburg Formation at Mt. Union (Locality 14 of the present paper) from "gray shale lens of typical Wills Creek lithology in the red beds" (written communication, 1959). The fossils collected are catalogued and identified in the Chicago Natural History Museum as follows:

"PE2950a tergite of large *Pterygotus*.

PE2950b fragment of integument, *Pterygotus* sp.
PE2950 five specimens, fragments of eurypterids, some being *Pterygotus*.
uncatalogued (field no. 101-51) possibly a leperditid.
PE157 *Hughmilleria* sp."

The writer has not seen these specimens or collected similar material from the Bloomsburg Formation. Thus the eurypterids are not included in the detailed descriptions.

TABLE 1. Faunal list and occurrence of the fossils in "red beds" and "marine" strata*

	"RED BEDS"	"MARINE"
FORAMINIFERA		
Bathysiphon cf. *B. exiguus* Moreman	VR	
Lagenammina cf. *L. cornuta* Grubbs	VR	
L. cf. *L. stilla* Moreman	VR	
COELENTERATA		
Favosites cf. *F. niagarensis* Hall		C
Favosites sp.	VR	
BRYOZOA		
Genus and species undetermined	R	R
BRACHIOPODA		
Lingula sp.	C	
Stegerhynchus andrewsi (Prouty)		VC
Genus and species undetermined	C	
ANNELIDA		
Cornulites sp.		VR
PELECYPODA		
Leiopteria sp.		C
Genus and species undetermined	VR	
GASTROPODA		
Genus and species undetermined	VR	
TENTACULOIDEA		
Tentaculites sp.	VR	R
OSTRACODA		
Paraechmina depressa Ulrich and Bassler		R
P. inaequalis Ulrich and Bassler	VR	R
P. postica Ulrich and Bassler	VR	C
Velibeyrichia mesleri (Ulrich and Bassler)	C	VC
V. tricornia n. sp.	R	VC
V. waldronensis (Ulrich and Bassler)		R
Dibolbina lobata n. sp.	VR	R
Pseudobeyrichia simplex n. sp.	R	
P. ventrilirata n. sp.	R	C
Kloedenia normalis Ulrich and Bassler	VC	R
Kyanodes? tricornis Ulrich and Bassler	VR	C
Bolbiprimitia subaequata (Ulrich and Bassler)	R	
Kloedenella berdanae n. sp.	R	VR
K. cristata n. sp.	R	

	"RED BEDS"	"MARINE"
K. gibberosa Ulrich and Bassler	C	VC
Eukloedenella curta Ulrich and Bassler	R	
E. sinuata Ulrich and Bassler	VR	C
E. umbilicata Ulrich and Bassler	R	C
E. sp.	C	
Dizygopleura gibba Ulrich and Bassler	VR	C
D. halli (Jones)	C	
D. perrugosa Ulrich and Bassler	VR	C
D. pulchella (Ulrich and Bassler)	VR	
D. punctella n. sp.	VC	
D. swartzi Ulrich and Bassler		VR
D. unipunctata Ulrich and Bassler		VR
D. ventrisulcata n. sp.	R	VR
Herrmannina willsensis (Ulrich and Bassler)	R	VR
H. sp.	C	
"Bythocypris" cf. "B." pergracilis Ulrich and Bassler	R	
"Bythocypris" philipsiana (Jones and Holl)	R	C
ECHINODERMATA		
Crinoid columnals	VR	R
CHORDATA		
Heterostracid scales	R	
?Agnathid scales	R	

* The "RED BEDS" include the Bloomsburg Formation, the Rabble Run Member of the Mifflintown Formation, and the included beds that are nonred. The "MARINE" strata include the Upper Member of the Mifflintown Formation and the Cedar Cliff Limestone Lentil. The abundance citations (VR-very rare, R-rare, C-common, VC-very common) are rough estimations of the species abundance based on the number of specimens recovered as well as the number of localities at which they are found.

DETAILED DESCRIPTIONS

Phylum PROTOZOA
Class SARCODINA
Order FORAMINIFERA
Family RHIZOMMINIDAE, Cushman
Genus BATHYSIPHON M. Sars, 1872

Type species: Bathysiphon filiformis M. Sars, 1872

BATHYSIPHON cf. B. EXIGUUS Moreman
Pl. 1, fig. 5

(cf.) *Bathysiphon exiguus* Moreman, 1930, p. 46, pl. 6, fig. 8.
Stewart and Priddy, 1941, p. 370, pl. 54, fig. 7.

Remarks.—A few broken specimens have been found that may be referable to this species. Unlike Moreman's material the Bloomsburg speci-

mens are composed of very-fine-grained sand. The Bloomsburg specimens are also larger than Moreman's; the diameter of the Bloomsburg specimens ranges from .28 to .44 mm.

Occurrence.—Locality 6, unit 11; locality 9, unit 3.

Family SACCAMMINIDAE Eimer and Fickert
Genus LAGENAMMINA Rhumbler, 1911

Type species: Lagenammina laguncula Rhumbler, 1911

LAGENAMMINA cf. L. CORNUTA Grubbs
Pl. 1, figs. 1, 2

(cf.) *Lagenammina cornuta* Grubbs, 1939, pps. 544-545, pl. 6, fig. 5, 6.

Remarks.—Three specimens were found at one locality that seem referable to this species. They agree in size and general shape with Grubbs' figures. Several other specimens were found that may belong to this form but that do not have any neck. It is suspected that the crushing of the rock destroyed the neck portion of the test and left only the spherical portion.

Occurrence.—Locality 9, unit 3.

LAGENAMMINA cf. L. STILLA Moreman
Pl. 1, figs. 3, 4

(cf.) *Lagenammina stilla* Moreman, 1930, p. 51, pl. 6, fig. 9.
Ireland, 1939, pl. A, fig. 22.

Remarks.—Several specimens from three localities are referred to this species. The Bloomsburg specimens agree with the description of *L. stilla* Morman in composition and general shape. The dimensions of these Bloomsburg specimens are about three times the dimensions given by Moreman. The length of the Bloomsburg specimens range from .72 to .76 mm. and the diameter from .46 to .48 mm.

Occurrence.—Locality 9, unit 3; Locality 13, unit 8; Locality 14, unit 8.

Phylum COELENTERATA
Class ANTHOZOA
Order TABULATA
Family FAVOSITIDAE Dana
Genus FAVOSITES Lamarck, 1816

Type species: Favosites gothlandicus Milne-Edwards and Haime, 1850.

FAVOSITES? species
Not figured.

Remarks.—Only one specimen of this phylum was obtained from the red beds of the Bloomsburg Formation. It is placed in the genus *Favosites* because of its resemblance to *Favosites* cf. *F. niagarensis* Hall which has

been identified from the marine limestones of the Mifflintown Formation.

Occurrence.—Locality 8, unit 17.

Phylum Bryozoa
Genus and species undetermined.
Not figured.

Remarks.—Small rod-shaped fragments of a poorly preserved bryozoan occur in several red bed samples. In all cases the original shell material has been in part replaced by the hematite from the claystone and the preservation is such that identification is impossible. As far as can be seen all the specimens belong to the same general form as the rhomboporoids.

Occurrence.—Locality 8, units 13, 14, 15 and 17; Locality 9, units 3 and 5; Locality 12, unit 10; Locality 13, unit 16; Locality 14, units 9, 10 and 12.

Phylum Brachiopoda
Class Inarticulata
Superfamily Lingulacea Waagen
Genus Lingula Bruguière, 1792

Type species: Patella unguis Linnaeus, 1758.

Lingula species
Not figured.

Lingula is a relatively common brachiopod in the Bloomsburg Formation but due to its fragile character it is almost always found as fragments. The few relatively complete specimens cannot be assigned to any species. In general outline they are similar to *Lingula subtruncata* Prouty (1923, p. 414, pl. 15, fig. 3) and *Lingula* sp. (ibid. pl. 15, figs. 5-7) found in the Bloomsburg and Mifflintown Formations of Maryland.

Occurrence.—Locality 2, units 7, 8, and 9; Locality 3, units 10 and 11; Locality 4, unit 2; Locality 5, unit 19; Locality 6, unit 11; Locality 7, units 6, 7, and 9; Locality 8, units 13 and 17; Locality 9, units 3 and 5; Locality 10, units 3, 6, and 7; Locality 11, units 1, 5, and 9; Locality 13, units 3 and 20; Locality 14, units 3 and 12; Locality 15, units 1 and 12.

Superfamily Rhynchonellacea Schuchert
Genus and species undetermined.
Not figured.

Remarks.—Several samples from the Bloomsburg Formation contain fragmentary remains of an articulate brachiopod probably belonging to the camerotoechids. It is possible that these specimens may be conspecific with *Stegerhynchus andrewsi* (Prouty) which is common in some of the marine limestones correlative with the Bloomsburg Formation. The speci-

mens obtained in the present study are not well enough preserved for generic or specific identification. Assignment to the Superfamily Rhynchonellacea is made on the similarity the specimens bear to the known rhynchonellid brachiopods from correlative marine limestones.

Occurrence.—Locality 2, unit 8; Locality 4, unit 5; Locality 5, unit 12; Locality 6, unit 4; Locality 7, unit 5; Locality 8, units 13, 14, and 15; Locality 9, units 3, 4, and 5; Locality 12, units 7, 9, 10, and 14; Locality 13, units 16 and 18; Locality 14, units 3 and 9; Locality 15, unit 7; Locality 17, unit 7.

Phylum MOLLUSCA

Class PELECYPODA

Genus and species undetermined.

Not figured.

Remarks.—The Bloomsburg Formation at a few localities contains a small number of very poorly preserved fossils that are identifiable only as pelecypods. The valve fragments are worn and were probably subject to some preburial movement. Suggesting the familial or generic affinities of these specimens is not possible until further material is found.

Occurrence.—Locality 8, unit 5; Locality 9, unit 4; Locality 13, unit 16.

Class GASTROPODA

Genus and species undetermined.

Not figured.

Remarks.—Gastropoda are extremely rare in the Bloomsburg Formation. Only two poorly preserved specimens were obtained from the red beds and identification of these specimens is impossible. They are similar to a few poorly preserved hormotomid gastropods that were found in the Cedar Cliff Limestone.

Occurrence.—Locality 5, unit 7; Locality 12, unit 6; Locality 18.

Class CONICONCHIA

Order TENTACULOIDEA

Genus TENTACULITES Schlotheim, 1820

Type species: Tentaculites scalaris, Schlotheim, 1820

TENTACULITES sp.

Not figured.

Remarks.—*Tentaculites* sp. has been found at a few localities in association with ostracods. The few recovered specimens of this genus are fragmental and nondescript. It is possible that they are conspecific with *Tentaculites niagarensis* Hall (Swartz and others, 1923, p. 492, pl. 31, figs. 5, 6) found in the Mifflintown Formation of Maryland.

Occurrence.—Locality 9, unit 5; Locality 14, unit 10; Locality 16, unit 7; Locality 17, unit 7.

Phylum ARTHROPODA
Class CRUSTACEA
Order OSTRACODA
Suborder PALEOCOPA
Superfamily BEYRICHIACEA
Family DREPANELLIDAE Ulrich and Bassler
Subfamily AECHMININAE Boucek
Genus PARAECHMINA Ulrich and Bassler, 1923

Type species: Cytherina spinosa Hall, 1852, by original designation of Ulrich and Bassler, 1923, p. 302.

PARAECHMINA DEPRESSA Ulrich and Bassler, 1923
Pl. 1, figs. 6-8

Paraechmina depressa Ulrich and Bassler, 1923, p. 509, pl. 38, fig. 22.

Occurrence.—*P. depressa* is a very rare species found only in the upper member of the Mifflintown Formation at Hollidaysburg (Locality 16, unit 7) and Mt. Union (Locality 14, unit 10).

PARAECHMINA INAEQUALIS Ulrich and Bassler, 1923
Pl. 1, fig. 9

Paraechmina inaequalis Ulrich and Bassler, 1923, p. 510-511, pl. 38, figs. 16-18.

Occurrence.—This species has been found in both the limestones of the upper member of the Mifflintown Formation and the red beds of the Bloomsburg Formation but it is very rare. It is found at Locality 9, unit 5; Locality 14, unit 10; Locality 17, unit 7.

PARAECHMINA POSTICA Ulrich and Bassler, 1923
Pl. 1, figs. 10, 11

Paraechmina postica Ulrich and Bassler, 1923, p. 507-508, pl. 38, figs. 6-10.

Remarks.—The specimens of this species obtained from the Bloomsburg and Mifflintown Formation agree very closely with the type specimens. The Bloomsburg and Mifflintown specimens differ slightly from the type specimens in that the anterior lobe is somewhat less pronounced in the former and all the specimens of right valves that the writer has obtained have the dorsal spine pointing posterodorsally rather than dorsally as shown in Ulrich and Bassler's fig. 9.

Occurrence.—Locality 9, unit 3; Locality 14, unit 10; Locality 16, unit 7; Locality 17, unit 7.

Family BEYRICHIIDAE Jones
Subfamily BEYRICHIINAE Jones
Genus VELIBEYRICHIA Henningsmoen, 1954

Type species: Beyrichia moodeyi Ulrich and Bassler, 1908, by original designation of Henningsmoen, 1954, p. 24.

VELIBEYRICHIA MESLERI (Ulrich and Bassler), 1923
Pl. 1, figs. 12-18

Beyrichia mesleri Ulrich and Bassler, 1923, p. 653, pl. 63, figs. 17-20.

Remarks.—The specimens of *V. mesleri* from the upper member of the Mifflintown Formation and the Bloomsburg Formation differ from the type specimens in that the horns of L_1 and L_3 are somewhat more pronounced. This is considered a minor local variation.

Occurrence.—Locality 5, unit 12; Locality 6, units 4 and 6; Locality 7, unit 5; Locality 8, units 13, 14, and 15; Locality 9, units 3, 4, and 5; Locality 10, unit 6; Locality 11, unit 3; Locality 12, unit 10; Locality 13, units 10, 16, 18, and 20; Locality 14, units 9 and 10; Locality 16, unit 7; Locality 17, unit 7.

VELIBEYRICHIA TRICORNIA n. sp.
Pl. 1, figs. 19-26

Description.—Outline subovate to semicircular. Dorsal border straight. Posterior border narrowly rounded, some specimens with a slight swing. Ventral border evenly rounded. Anterior border nearly straight. Posterior cardinal angle 90 degrees to slightly obtuse. Anterior cardinal angle slightly obtuse.

S_1 short, narrow, widens near dorsal margin, straight, extends about one-quarter of height to ventral margin. S_2 narrow, widens near dorsal margin and near base of sulcus, extends slightly more than one-half of distance to ventral margin.

L_1 short, wide, dorsally extends into a horn that projects slightly above the dorsal border. L_2 broad, low, narrows to a low horn just above the hinge line. L_3 very broad, low, comprises all the area posterior to S_2, dorsally extends into a horn projecting above the dorsal border.

Ventral areas evenly convex to ventral border. Anteroventral depression nonexistant or only slightly impressed.

Frill narrow, faintly striate, triangular in cross section, internally compartmented, ventrally extends beyond free edge, anteriorly and posteriorly originates near midheight. In most specimens frill not set off from rest

of valve by extralobate groove; in some specimens a faint extralobate groove is present.

Females differentiated from males by presence of very large bulbous pouch in the anteroventral region. Surfaces other than frill unornamented. Average size of adult male: length 1.67 mm., height 1.07 mm., width .88 mm.

Remarks.—*Velibeyrichia tricornia* is similar to *V. mesleri* in many features. It can be separated from *V. mesleri* by the weakness of the definition of the lobes and the absence of a deep anteroventral depression and a pronounced extralobate groove. The frill of *V. mesleri* is set at an angle to the curvature of the carapace while the frill of *V. tricornia* lies in the curvature of the carapace.

V. tricornia may also be confused with the left valve of *Kyamodes? tricornis* Ulrich and Bassler, 1923, particularly those specimens in which the frill striae are not pronounced. *K.? tricornis* has no frill and the lobation—particularly the curved L_1—suffice to distinguish the two species.

This species of *Velibeyrichia* is most unusual. All other known species of this genus have the frill set at an angle to the curvature of the carapace, and the frill of these species is a structure with little thickness. The frill of *V. tricornia* is triangular in cross section and compartmented by thin partitions. The striate nature of the frill in many specimens is the result of the differential color of the partitions and the shell material over the compartments and not by a grooving of the frill surface as in *V. mesleri*.

Occurrence.—Locality 6, unit 6; Locality 8, units 14 and 15; Locality 9, unit 5; Locality 12, unit 9; Locality 13, unit 18; Locality 16, unit 7; Locality 17, units 7 and 9.

Types.—Holotype, a male right valve, USNM 143201; Paratypes, a female right valve, USNM 143202a; a female left valve, USNM 143202b; a male left valve, USNM 143202c; a male right and left valve artificially joined, USNM 143202d; rock specimen with several valves, USNM 143202e.

Velibeyrichia waldronensis (Ulrich and Bassler), 1908

Pl. 1, figs. 27-30

Beyrichia waldronensis Ulrich and Bassler, 1908, p. 286, pl. 37, figs. 9, 10.

Remarks.—The specimens that were obtained of this species differ slightly from the holotype, but not sufficiently to designate them as a separate species or variety. The holotype and several specimens of *V. waldronensis* from the Waldron shale supplied by Dr. Jean M. Berdan of the U. S. Geological Survey were examined and compared to the specimens obtained from the Mifflintown Formation.

The Mifflintown specimens differ from the holotype and some of the

Waldron specimens in that the punctation of the lobes does not continue across the zygal ridge; some of the Waldron specimens also show this same absence of punctation on the zygal ridge. Some immature moults from the Mifflintown Formation have a few punctae on the zygal ridges.

The figures of *V. waldronensis* in the original publication (Ulrich and Bassler, 1908) show the frill to be very wide throughout its extent. Whether this is true or not cannot be determined because only one of the cotypes is extant, and this is not complete. The frill of the remaining cotype is broken along the posterior, posteroventral and anterior margins so that its true extent is not determinable. It is doubtful that the frill is as wide as figured by Ulrich and Bassler because all the specimens of *V. waldronensis* from the Waldron shale show the frill to be narrow anteriorly and posteriorly and wide ventrally as in the Mifflintown specimens.

The L_1 of the Mifflintown specimens is somewhat narrower than in the holotype and the Waldron specimens; this is such a slight difference it is doubtful that it has any significance.

Occurrence.—Locality 14, unit 10; Locality 16, unit 7; Locality 17, unit 7.

Genus DIBOLBINA Ulrich and Bassler, 1923

Type species: Dibolbina cristata Ulrich and Bassler, 1923, p. 312, by original designation.

DIBOLBINA LOBATA n. sp.
Pl. 2, figs. 18-23

Description.—Outline semicircular. Dorsal border straight. Posterior border narrowly rounded. Ventral border evenly rounded. Anterior border straight to narrowly rounded. Both cardinal angles slightly obtuse.

Weakly bisulcate. S_1 short, very ill defined, completely absent on a few specimens, originates just below dorsal margin. S_2 narrow, originates below dorsal margin and extends to near midheight where it deepens slightly.

L_1 comprises the area anterior to S_1, low, ill defined, in some specimens with a slight dorsal horn. L_2 broad, low, somewhat triangular in outline, disappears before reaching dorsal margin. L_3 comprises all the area posterior to S_2, moderately convex, ill defined.

Anteroventral depression slightly impressed along the extralobate groove in the area just below S_1, in some specimens nonexistant.

Frill very wide, striate, originates near the cardinal angles where it is very narrow, gradually increases in width until it reaches its maximum just below S_2 and L_3. Extralobate groove pronounced.

Female form not observed. Presumably it will be similar to other fe-

males of this genus. Surfaces other than frill unornamented. Dimensions of an adult male: length 1.64 mm., height with frill 1.20 mm., height without frill .76 mm., width with frill 1.60 mm., width without frill .88 mm.

Remarks.—This species differs from *D. cristata* and *D. producta* of the Tonoloway Formation of Maryland by the presence of the S_1 and the more pronounced lobes. It also differs from them in outline, *D. cristata* and *D. producta* are long relative to their height and have acuminate cardinal angles. This species differs from *D. steusloffi* (Krause) in the less impressed sulci.

Ulrich and Bassler defined this genus primarily on the absence of the characteristic beyrichian (velibeyrichian) lobation and the greatly extended frill. *V. lobata,* while possessing the beyrichian lobation in much reduced form, seems to agree in general with the sense of their genus and may be regarded as one of the earlier forms transitional from a beyrichian ancestor.

Occurrence.—Locality 8, unit 15; Locality 14, unit 10; Locality 16, units 7 and 9.

Types.—Holotype, a male left valve, USNM 143203; Paratypes, two male left valves, USNM 143204a and 143204b; a male right valve, USNM 143204c.

Genus Pseudobeyrichia Swartz and Whitmore, 1956

Type species: Pseudobeyrichia perornata Swartz and Whitmore, 1956, p. 1061, by original designation.

Remarks.—This genus was based solely on the type species. Two species from the Bloomsburg and Mifflintown Formations, an undescribed species from the Manlius Formation of New York, and possibly *Beyrichia gregaria* Grubbs (1939, p. 559, pl. 62, figs. 35-39) from the Niagaran of the Chicago area are believed to belong to this genus.

Consideration of all these species indicates that the generic characteristic common to most of the species is the deep median sulcus (S_2). Common to all the species are the protuberant, knoblike L_2, the low velate ridge that parallels the free edge, the tendency for the hinge line to be surrounded by a flattened area, and the dimorphic swelling which is somewhat less well defined than is usual in the Beyrichiinae. The lobation and ornamentation vary somewhat. L_1 in most of the included species is very low and merges with the body of the valve. L_2 is pronounced in all the species and varies from a rounded bulbous shape to somewhat triangular. L_3 is usually low and not pronounced. The ornamentation ranges from none in the male specimens of *Pseudobeyrichia simplex* n. sp. to punctate and granulose in the type species.

Pseudobeyrichia ventrilirata n. sp.

Pl. 2, figs. 1-7

Description.—Outline subelliptical. Dorsal border straight. Posterior border straight to narrowly rounded. Ventral border evenly rounded. Anterior border narrowly rounded. Posterior cardinal angle 90° to slightly obtuse. Anterior cardinal angle moderately obtuse.

S_1 a semisulcus, extends from near midheight to near dorsal margin as the anterior border to L_2. S_2 narrow, deep, widens at top and ends before reaching dorsal margin, extends to near midheight.

L_1 low, comprises area anterior to S_1. L_2 broad, moderately pronounced, dorsally somewhat pointed, extends to about midheight, ventrally connected to carinae by very low, thin crest. L_3 comprises the area posterior to S_2, very broad, not well defined, dorsally produced into slight hump on each valve. Hump in dorsal view creates flattened area parallel to hinge line that extends anteriorly beyond L_2.

Two thin carinae near midheight, close together, roughly paralleling free margin. Carinae originate near midheight in the posterocentral area and continue to central anterior area where they become low and indistinct, Carinae continue very low and curve dorsally in an arc. Near dorsal margin curve increases and carinae, which are now one thin ridge, curve to meet top of L_2.

Velate ridge low, originates near anterior cardinal angle and parallels free edge to near the posterocentral area where it disappears.

Females very distinctive and characterized by swelling of anterocentral and surrounding regions. Swelling obliterates in part ventral portion of L_2 and anterior portions of carinae. In ventral view dimorphic structure creates a small ridge in the channel.

Ornamentation other than discussed nonexistent. Average adult male measures: Length 1.20 mm., height .76 mm., width .64 mm. Female measurements similar except in width; average female width .84 mm.

Remarks.—*Pseudobeyrichia ventrilirata* is distinguished from the other species of the genus by its distinctive carinal ornamentation.

Occurrence.—Locality 8, unit 17; Locality 10, units 6, 7, and 8; Locality 11, unit 9; Locality 14, unit 12; Locality 16, units 7, 8, and 9.

Types.—Holotype, a male carapace, USNM 143205; Paratypes, a female carapace, USNM 143206a; a male carapace, USNM 143206b (unfigured); a male left valve, USNM 143206c (unfigured).

Pseudobeyrichia simplex n. sp.

Pl. 2, figs. 8-17

Description.—Outline subelliptical. Dorsal border straight. Posterior border straight to narrowly rounded. Ventral border evenly rounded. An-

terior border evenly rounded. Posterior cardinal angle slightly obtuse. Anterior cardinal angle moderately obtuse.

S_1 a semisulcus bordering anterior portion of L_2. S_2 narrow, shallow, ill defined, extends to near midheight, ends below dorsal margin.

L_1 low, comprises area anterior to S_1. L_2 a rounded, knoblike, lobe set about one-third of height from dorsal margin. L_3 comprises the area posterior to S_2, low, ill defined, evenly convex to margins.

Velate ridge low, originates at anterior cardinal angle and extends to posterior cardinal angle.

Females distinguished by swelling of the anteroventral and surrounding areas. Dimorphic structure regularly striate ventrally and laterally. Other portions of females and all of males completely unornamented. Average adult male measures: length 1.20 mm., height .68 mm., width .52 mm.

Remarks.—This species is distinguished by its simplicity of lobation and surface. It differs from the other species of the genus in that S_2 is not a deep and pronounced structure. It is the writer's opinion that the presence of the velate ridge, the knoblike L_2, and the similarity of the dimorphic swelling to the other species of the genus suffice to include it in *Pseudobeyrichia.*

Most of the specimens of this species that were recovered were distorted in some way. This is unusual because few specimens of the other species extracted in the same manner and from the same lithology exhibited any distortion. It is possible that the shell material of *P. simplex* was composed of material less strong than the shell material of other species. If the shell material of *P. simplex* was of material similar to that of some of the living fresh water ostracods it is possible that this would account for their distortion after burial.

Occurrence.—Locality 8, unit 3; Locality 9, units 1 and 3; Locality 13, unit 8; Locality 14, unit 8.

Types.—Holotype, a male carapace, USNM 143207; Paratypes, 3 male carapaces, USNM 143208a, 143208b, 143208c, a partial female right valve, USNM 143208d.

Subfamily KLOEDENIINAE Ulrich and Bassler
Genus KLOEDENIA Jones and Holl, 1886

Type species: Beyrichia wilckensiana Jones, 1855, by subsequent designation of Ulrich and Bassler, 1908, p. 300.

KLOEDENIA NORMALIS Ulrich and Bassler, 1923
Pl. 3, figs. 4-20

Kloedenia normalis Ulrich and Bassler, 1923, p. 639, pl. 61, figs. 15-19,

Text-fig. 18 (6, 7), p. 306. ———, Bassler and Kellett, 1934, fig. 9 (6, 7) p. 24. ———, Swartz, 1936, pl. 84, figs. 5c, 5d.
Kloedenia normalis var. *appressa* Ulrich and Bassler, 1923, p. 639, pl. 61, figs. 20-22.

Kloedenia cacaponensis Ulrich and Bassler, 1923, p. 640, pl. 61, figs. 24, 25.
Kloedenia kenziensis Ulrich and Bassler, 1923, p. 640, pl. 61, fig. 23.
Zygobeyrichia ventricornis Ulrich and Bassler, 1923, p. 646, pl. 54, figs. 6-8, *not* fig. 11.
Zygobeyrichia ventricornis var. *obsoleta* Ulrich and Bassler, 1923, p. 646, 647, pl. 54, figs. 9, 10.

Remarks.—Kloedenia normalis was found in 207 of the 268 samples collected from the Bloomsburg Formation and its correlative units, and a few hundred specimens of this species were observed. From examination of this great number of specimens it was readily apparent to the writer that *K. normalis* is very variable in its individual expression.

The first and most obvious individual variation that was observed was in the possession of a ventral spine or node. In many of the samples individuals with a ventral node and individuals without a node as well as one with a faint node were found together. No other features could be found to separate the variants. Another significant variation concerns the ventral border. Many specimens from one sample would bear a well defined border while others would have only a portion of a border or no border at all. The length and the strength of the sulci and valve convexity also were observed to be affected by individual variation.

After examination of all these specimens it was apparent to the writer that a few of the species of *Kloedenia* and some species of other genera that had been described by Ulrich and Bassler in the Maryland Silurian Volume were species variants that cannot be separated from the type specimens of *K. normalis* by any consistent or diagnostic features. All of the type specimens of the species considered to be in synonomy with *K. normalis* were examined and compared to the type specimens of this species, prior to final inclusion in the synonomy. Each of the synonomous forms is discussed below.

The variety *appressa* of *K. normalis* does not properly constitute a variety; it differs in no significant respect from the type specimens of *K. normalis* except in its smaller size. The specimens assigned to the variety are considered to be immature moults of the species because of their small size and the absence of females of a similar size.

Kloedenia cacaponensis Ulrich and Bassler is also considered to belong to *K. normalis*. This form was deemed by Ulrich and Bassler to be similar

to *K. normalis* but differing mainly in its outline, absence of a ventral border, greater valve convexity, and straighter sulci. The features exhibited by the cotypes, an immature moult and an adult female, do not depart sufficiently from the types of *K. normalis* to be considered a separate species.

Kloedenia kenziensis Ulrich and Bassler was distinguished from *K. normalis* by its different outline and the weakness of its sulci. Variation in outline, based on the Bloomsburg specimens, is not diagnostic. The weakness of the sulci in *K. kenziensis* also does not appear to be significant enough to maintain the separation of these species.

The specimens that were assigned to *Zygobeyrichia ventricornis* Ulrich and Bassler carry none of the features that would place them in *Zygobeyrichia*. This fact was realized by Henningsmoen (1954, p. 31, 32) who erected for this and two other species the new genus *Cornikloedenia,* using the ventral ridge and spine as the diagnostic generic criterion. *Drepanlellina ventralis* Ulrich and Bassler was chosen as the type species and *Drepanellina claypolei* Ulrich and Bassler was also included in the genus.

Examination of the Bloomsburg ostracods showed that specimens identical to *Z. ventricornis* were nearly always found with *K. normalis* and that gradations between the two forms could be found. No other feature was observed that would separate the two forms. When it was established that *Z. ventricornis* was conspecific with *K. normalis* it was suspected that possibly the other species of the genus *Cornikloedenia* were conspecific with *K. normalis*. This was found not to be true.

The type specimens of *Drepanellina ventralis* were re-examined and it was found that this form constitutes a separate species. It differs from *K. normalis* by the possession of a short, low ventral ridge that parallels the ventral margin. The cotype specimens are about the same size as the cotypes of *K. normalis* but other specimens (USNM 82995) identified as *Kloedenia ventralis* from the "*Drepanellina clarki* zone" at Hollidaysburg, Pa. are about one and one-half times larger than the usual *K. normalis,* and have fine punctae.

The affinities of the specimen that bears the name *Drepanellina claypolei* are doubtful. The specimen is incomplete and poorly preserved and only the holotype has ever been found. The specimen is in such poor shape that *D. claypolei* should be considered a *nomen dubium* until better material is found. At the present time it is not possible to give the specimen a generic classification. It is possible that better material will show that this specimen truly belongs to a different genus than its previous assignment.

The criteria on which the genus *Cornikloedenia* was erected do not seem valid. One of its species, *Zygobeyrichia ventricornis* is considered conspecific with *K. normalis*. *Drepanellina claypolei* is considered a *nomen*

dubium. This leaves only the species *Drepanellina ventralis* as a valid species. In the opinion of the writer the characteristics that define this species are not of generic importance. This species bears such close relationship to known American species of *Kloedenia* that the writer feels it should be placed in that genus. Thus, *Cornikloedenia* should be placed in synonomy with *Kloedenia*.

Zygobeyrichia ventricornis var. *obsoleta* Ulrich and Bassler is essentially identical with *K. normalis*. The specimens assigned to the variety do not bear a ventrally extended S_1 and thus are not *Zygobeyrichia* and they have no indication of a ventral structure of any sort. The writer can see no significant difference between these specimens and those of *K. normalis*.

A few other species were examined because of their similarity to *K. normalis*. *Zygobeyrichia incipiens* Ulrich and Bassler (1923, p. 646, pl. 54, figs. 13, 14) was examined and is considered to be a true *Zygobeyrichia* because S_1, although very faint, continues to very near the ventral border. In most other respects the two species are very similar and would require close examination to separate them. The specimen that was figured as *Zygobeyrichia ventricornis* var. (Ulrich and Bassler, 1923, pl. 54, fig. 11) is a true *Zygobeyrichia* and is probably an immature moult of *Zygobeyrichia tonolowayensis* Ulrich and Bassler. *Kloedenia longula* Ulrich and Bassler, (1923, p. 640, pl. 61, figs. 30, 31) is more closely allied to the genus *Zygobeyrichia* than *Kloedenia* because S_1 of this species definitely extends to near the ventral border as in the other true species of *Zygobeyrichia*. Using the same criteria for generic affinities the species *Zygobeyrichia modesta* Ulrich and Bassler (1923, p. 647, pl. 54, fig. 12) belongs to *Kloedenia* because there is no trace of a ventral continuation of S_1. *K. modesta,* while similar to *K. normalis,* differs sufficiently to maintain its specific identity.

Occurrence.—Locality 2, unit 8; Locality 3, units 3, 6, 10, 12, and 13; Locality 4, units 2, 4, and 5; Locality 5, units 7, 9, 11, 12, and 15; Locality 6, units 2, 4, 6, and 11; Locality 7, units 5, and 6; Locality 8, units 5, 11, 13-15, and 17; Locality 9, units 1, and 3-5; Locality 10, units 3, 4, and 6-8; Locality 11, units 1, 3, 5, and 6; Locality 12, units 1, 6, 7, and 14; Locality 13, units 1, 3, 10, 14, 16, and 20; Locality 14, units 1, 3, 8, and 12; Locality 15, units 1, 10-12, and 14; Locality 16, units 7-9; Locality 17, units 7-9; Locality 18; Locality 19; Locality 20, unit 3.

Genus Kyamodes Jones, 1888

Type species: Kyamodes whidbornei Jones, 1888, p. 295-296, by original designation.

KYAMODES? TRICORNIS Ulrich and Bassler, 1923
Pl. 2, figs. 24-31

Kyamodes tricornis Ulrich and Bassler, 1923, p. 644, pl. 55, figs. 1-5.
Kloedenia tricornia, Henningsmoen, 1954, p. 30, 32.

Remarks.—Henningsmoen (1954, p. 32) states that *Kyamodes tricornis* does not agree with the generic characteristics of the type species *K. whidbornei,* but that it does agree with the genus *Kloedenia.* The writer has examined the type specimens of *K.? tricornis* as well as several specimens from the upper member of the Mifflintown Formation. It is the writer's opinion after this examination that *K.? tricornis* is not a *Kloedenia* because of the characteristics of the ventral portion of the valves. Not only does the left valve extend ventrally beyond the free edge but also the right valve has a narrow flange that fits within the left valve. The position of the right valve flange within the left valve is marked with a shallow groove. To the writer's knowledge none of the species of *Kloedenia* have similar ventral characteristics.

It is possible that Henningsmoen's opinion that this species belongs to another genus than *Kyamodes* is correct. Until the type species of *Kyamodes* can be examined and compared to *K.? tricornis* the author prefers to questionably assign the species to this genus. One other species, *Drepanellina confluens* Ulrich and Bassler (1923, p. 649-650, pl. 56, figs. 7-9) should also be included in consideration of *K.? tricornis. D. confluens* almost certainly is not a *Drepanellina* and bears a great resemblance to *K.? tricornis.* It is possible that these two species may constitute a genus separate from *Kloedenia* and *Kyamodes.*

Occurrence.—Locality 9, unit 5; Locality 13, unit 20; Locality 14, units 9, and 10; Locality 16, unit 7; Locality 17, unit 9.

Subfamily TREPOSELLINAE Henningsmoen
Genus BOLBIPRIMITIA Kay, 1940

Type species: Halliella fissurella Ulrich and Bassler, 1923, by original designation of Kay, 1940, p. 252.

BOLBIPRIMITIA SUBAEQUATA (Ulrich and Bassler), 1923
Pl. 3, figs. 1-3

Halliella subaequata Ulrich and Bassler, 1923, p. 544, pl. 37, fig. 20.

Remarks.—In all the observed specimens that have the hinge line preserved S_2 ends just short of the dorsal margin and thus conforms to the major criterion of this species. The major difference that some of the Bloomsburg Formation specimens bear is the slight swelling of the region anterior to the sulcus so that it is more prominent than in the type specimens of the species. This swelling is apparently an individual feature.

Only one specimen was observed that might be considered a female. It differs from the males in that the ventral region is more convex and appears slightly swollen. However, the dimorphic region, if it is such, is not set off by any lines of demarcation. No females are among the type specimens so it is impossible to state definitely if this specimen is a true dimorph.

Occurrence.—Locality 3, unit 10; Locality 4, unit 2; Locality 6, unit 4; Locality 8, units 5, 11, and 13; Locality 9, unit 3; Locality 10, units 6-8; Locality 12, units 6 and 14; Locality 13, unit 3; Locality 14, unit 1; Locality 19.

Family KLOEDENELLIDAE Ulrich and Bassler
Subfamily KLOEDENELLINAE Ulrich and Bassler
Genus KLOEDENELLA Ulrich and Bassler, 1908

Type species: Kloedenia pennsylvanica Jones, 1889, by original designation of Ulrich and Bassler, 1908, p. 317.

KLOEDENELLA CRISTATA n. sp.
Pl. 4, figs. 10-15

Description.—Outline subelliptical. Dorsal view outline lanceolate. Dorsal border arched with moderate curvature. Posterior border subrounded. Posterior cardinal angle 90° to somewhat obtuse. Ventral border slightly sinuate in males, straight to slightly rounded in females. Anterior border evenly rounded. Hinge line depressed in posterior two-thirds due to height of humps on both valves.

S_1 narrow, arcuate, convex anteriorly, in left valve the dorsal portion extends into small hinge tooth, extends one-half the distance to ventral margin. S_2 short, pitlike, deepest at ventral end.

L_1 arcuate, convex anteriorly, low and indistinct, extends one-half the distance to ventral margin where it merges imperceptibly with anterior areas. L_2 low, depressed below height of L_1 and L_3, broadens at base where it merges with central areas, very convex antero-dorsally. In left valve L_2 continues dorsally as a narrow ridge to form top of left valve hump. In right valve L_2 continues dorsally to join with and form part of right valve hump. L_3 broad, indistinct, dorsally extends into moderate humps on both valves.

Right valve hump high, slightly arcuate, extends anteriorly from L_3 to posterior end of hinge tooth. L_2 of right valve merges with hump near its greatest convexity. Left valve hump low, extends from L_3 to join with L_2.

Females distinguished from males by swelling of the posterior areas. Swelling not as pronounced as in most other species of *Kloedenella*. Most carapaces unornamented, a few well preserved carapaces bear very-fine

punctae. Average size of adult: length 1.08 mm., height .61 mm., width .48 mm.

Remarks.—*Kloedenella cristata* is close to no other species of this genus except perhaps *Kloedenella nitida* Ulrich and Bassler. *K. cristata* differs from *K. nitida* in its smaller size, the dorsal extension of L_2 on each valve to join the humps, and the possession of humps on both valves. *K. nitida* has a hump only on the right valve, is larger, and has a less well developed L_1.

Occurrence.—Locality 4, unit 4; Locality 5, unit 7; Locality 6, unit 4; Locality 8, unit 11; Locality 9, unit 3; Locality 12, unit 6; Locality 17, unit 7.

Types.—Holotype, a female carapace, USNM 143209; Paratypes, 2 female carapaces, USNM 143210a, 143210b, 3 male carapaces, USNM 143210c, 143210d, 143210e.

KLOEDENELLA BERDANAE n. sp.

Pl. 4, figs. 1-9

Description.—Outline subelliptical. Dorsal border slightly to moderately arched. Posterior border rounded with slight swing in males, less rounded with moderate swing in females. Posterior cardinal angle moderately to slightly obtuse in males, slightly obtuse to 90° in females. Ventral border straight to slightly rounded. Anterior border evenly rounded.

S_1 long, broad, deep, crescentic, extends from dorsal margin to very near ventral margin where it curves posteriorly. In left valve S_1 dorsally produced into hinge tooth. S_2 short, narrow, deep, extends from just below dorsal margin to about midheight.

L_1 narrow, arcuate, ill defined, slopes directly to anterior margin. L_2 narrow, short, extends to near midheight. L_3 comprises area posterior to S_2, not well defined as a lobe, evenly convex.

In some specimens dorsal margin S_2 of right valve produced into low dorsal protuberance somewhat triangular in shape.

Females distinguished by swelling of posterior areas. Average size of adult male: length 1.12 mm., height .72 mm., width .49 mm.

Remarks.—This species is close to *Kloedenella gibberosa* Ulrich and Bassler, particularly those specimens with the dorsal protuberance. The two species can be differentiated on the shape of the S_1. S_1 in *K. gibberosa* is short and narrow and does not extend beyond midheight while S_1 in *K. berdanae* is long, broad, and crescentic.

Individual variations were observed mainly in the presence or absence of the dorsal protuberance.

Occurrence.—Locality 3, unit 10; Locality 4, unit 5; Locality 6, units 4 and 6; Locality 7, unit 5; Locality 8, units 13-15; Locality 9, unit 5;

Locality 10, unit 6; Locality 11, units 3 and 5; Locality 12, unit 10; Locality 13, unit 18.

Types.—Holotype, a male carapace, USNM 143211; Paratypes, 2 male carapaces, USNM 143212a, 143212b; 3 female carapaces, USNM 143212c, 143212d, 143212e.

KLOEDENELLA GIBBEROSA Ulrich and Bassler, 1923
Pl. 4, figs. 16-31

Kloedenella gibberosa Ulrich and Bassler, 1923, p. 680, 681, pl. 59, figs. 17, 18.

Kloedenella subovata Ulrich and Bassler, 1923, p. 679, pl. 59, figs. 11-13.

Remarks.—*Kloedenella gibberosa* is a very common species in the limestones and shales of the upper member of the Mifflintown Formation and in a few of the red bed units of the Bloomsburg Formation. Examination of several samples containing this species showed that various of its structures are subject to a considerable amount of individual variation. The species is characterized by the prominent, triangular-shaped dorsal protuberance on the right valve. This structure as well as the lateral outline, the sulci, and an unusual ventral thickening on the left valve are all subject to individual variation.

The dorsal protuberance differs in various individuals as to its height and shape. In some individuals it is barely present, in others it is very high. Its shape may be triangular and erect or swept back and pointing posterodorsally. The lateral outline differs most in the ventral portion. Some individuals have a pronounced sinuate ventral border while in others it is evenly rounded. The sulci may be deep and well defined or shallow and scarcely visible, in both cases the sulci retain the same position and general shape. The projection of the anterior portion of the free edge on a flange-like structure, which is present in the holotype specimen, may or may not be present. A few samples contain specimens of *K. gibberosa* that bear a thickening of the left valve that produces a flattened area along the ventral portion of the valve. Most specimens of *K. gibberosa* have a simple ventral overlap of left valve on the right valve without this ventral thickening.

Several samples from the lower Bloomsburg Formation contain an ostracod that differs from *K. gibberosa* only in its smaller size. That the small size is not due to their being immature moults is shown by the presence of female dimorphs in the same sample. This indicates that the specimens are adult. It is suggested that these specimens represent a variant of *K. gibberosa* that was adapted to the peculiarities of the depositional environment of the lower Bloomsburg. The few specimens of *K. gibberosa* that occur in the middle Bloomsburg Formation are of normal size.

In a few samples from the upper member of the Mifflintown Formation which provided a large number of well preserved specimens several of the immature instars of *K. gibberosa* were observed. The immature instars differ from the adult in that they are trisulcate and quadrilobate, features characteristic of the genus *Dizygopleura.*

The writer at first thought that the trisulcate and bisulcate specimens belonged to two species of different genera. Examination of over 200 specimens showed that the only difference was in the presence of S_3 in the small specimens and that the sulcus becomes less pronounced as the specimen size increases. Only a few of the adults bear any trace of the third sulcus and this is very faint.

The S_3 of the immature instars is short, arcuate, lying posterior to a short, broad, ill-defined L_3. The L_4 of the instars is narrow, arcuate, and most prominent in the earlier instars.

Many of the immature instars are exact duplicates of the specimens used to erect the species *Dizygopleura pinguis* Ulrich and Bassler (1923, p. 693, pl. 62, figs. 9, 10). It is possible that *D. pinguis* should be placed in synonomy with *K. gibberosa.* Final determination of that possibility awaits examination of material from the section where *D. pinguis* was collected to see if adult *K. gibberosa* are also present in the same samples.

It is also possible that *Kloedenella transitans* Ulrich and Bassler (1923, p. 681, pl. 61, figs. 19, 20), which occurs with *D. pinguis,* may be conspecific with *K. gibberosa,* and may be the adult form of the species at the localities where it is found. *K. transitans* differs from *K. gibberosa* in having deeper sulci, and in the one remaining cotype specimen, a very weak dorsal protuberance. Since the specimens of *K. gibberosa* from the Mifflintown Formation have been observed to exhibit considerable individual variation it is entirely possible that *K. transitans* is merely a variant of *K. gibberosa.*

Generically the adult specimens from the Mifflintown Formation belong to the genus *Kloedenella.* The fact that the immature instars of this species bear characteristics of the genus *Dizygopleura* suggest that *K. gibberosa* was possibly derived from *Dizygopleura.*

Occurrence.—Locality 4, unit 4; Locality 5, unit 12; Locality 6, units 6 and 11; Locality 7, units 9 and 11; Locality 8, units 13, 15, and 17; Locality 9, units 3-5; Locality 10, unit 8; Locality 11, units 3, 5, and 6; Locality 12, unit 7; Locality 13, units 10, 14, 16, 18, and 20; Locality 14, units 9, 10, and 12; Locality 15, units 10 and 12; Locality 16, units 7-9; Locality 17, units 7-9.

Genus EUKLOEDENELLA Ulrich and Bassler, 1923

Type species: Eukloedenella umbilicata Ulrich and Bassler, 1923, p. 313, by original designation.

EUKLOEDENELLA CURTA Ulrich and Bassler, 1923
Pl. 5, figs. 1-7

Eukloedenella umbilicata var. *curta* Ulrich and Bassler, 1923, p. 669, pl. 57, fig. 13.

Discussion.—Ulrich and Bassler (1923, p. 669) cited most of the differences that separate *E. curta* from *E. umbilicata* Ulrich and Bassler but considered it a variety rather than a separate species. *E. umbilicata* has a rounded outline in dorsal view, rather than angled somewhat posteriorly as in *E. curta*. The surface punctae are larger in well preserved specimens of *E. curta* than in *E. umbilicata*. These features coupled with the small size of *E. curta* set the species and variety apart. In the writer's opinion the differences are sufficient to raise the variety to species status.

The figure in the Maryland Silurian Volume (Ulrich and Bassler, 1923, pl. 57, fig. 13) is erroneous in that the outline does not agree with the holotype specimen in the U. S. National Museum from which the figure was drawn. The figure also does not show the punctae that are present on the holotype.

Occurrence.—Locality 5, unit 7; Locality 6, unit 4; Locality 8, unit 13; Locality 9, unit 3; Locality 10, unit 3.

EUKLOEDENELLA SINUATA Ulrich and Bassler, 1923
Pl. 5, figs. 14-16

Eukloedenella sinuata Ulrich and Bassler, 1923, p. 671, pl. 57, figs. 24-27.
Swartz, 1933, p. 260, pl. 30, figs. 7 a-d, 8 a-d.
Eukloedenella sinuata var. *angulata* Ulrich and Bassler, 1923, p. 672, pl. 57, figs. 28-31.
Eukloedenella dorsata Ulrich and Bassler, 1923, p. 673, pl. 58, fig. 6.

Discussion.—Swartz (1933, p. 260) noted that the males and females of this species had been described separately by Ulrich and Bassler, the males being the variety *angulata*. Examination of the type specimens of this species and other similar species shows that *E. dorsata* Ulrich and Bassler is conspecific with *E. sinuata*. The weakness of the S_2 ("umbilical depression" of Ulrich and Bassler) supposedly characterizing *E. dorsata* can also be found in some of the type specimens assigned to *E. sinuata*. In all other respects the two forms are alike and should be considered the same.

Occurrence.—Locality 8, unit 15; Locality 11, units 5 and 6; Locality 12, unit 9; Locality 13, units 18 and 20; Locality 14, unit 10; Locality 16, unit 7; Locality 17, unit 9.

EUKLOEDENELLA UMBILICATA Ulrich and Bassler, 1923
Pl. 5, figs. 8-13

Eukloedenella umbilicata Ulrich and Bassler, 1923, p. 669, pl. 57, figs. 8-12.

Remarks.—Many of the specimens of this species from the Bloomsburg and Mifflintown Formations are very close to the type specimens in the U. S. National Museum. A few are nearly identical with the cotypes. Some of the Mifflintown Formation specimens differ from the types in that the area posterior to S_2 may be projected dorsally into a low hump. The hump may project slightly above the hinge. Those specimens with a hump approach the shape of *Eukloedenella indivisa* Ulrich and Bassler (1923, p. 668, pl. 57, figs. 1-7) but differ from this species in that they all have a sulcus. S_2 in *E. umbilicata* may vary from a barely impressed pit to a deep pit, or, in those specimens with a hump, to a broad, open, shallow sulcus.

Several samples contained enough specimens to determine the number of instars present. Besides the adult, 8 immature instars were found. The surface characteristics remain the same in the instars except for the increase in definition of the sulcus and slight changes in the dorsal view outline so that it is not so evenly convex.

Occurrence.—Locality 4, unit 5; Locality 5, unit 12; Locality 6, units 4 and 6; Locality 7, unit 6; Locality 8, unit 7; Locality 9, unit 3; Locality 10, units 6 and 8; Locality 11, unit 9; Locality 14, units 8, 9, and 12; Locality 15, unit 11; Locality 16, units 7-9; Locality 17, units 7-9.

EUKLOEDENELLA species
Not figured.

Remarks.—Several samples from the Bloomsburg Formation contain separated valves and complete carapaces of an ostracod that is presumably *Eukloedenella,* but that does not fit with any of the above species. Most of the specimens are poorly preserved. Many of them are a simple smooth carapace with no S_2, or none preserved. Because of their nondescript character these specimens are simply referred to the genus.

Occurrence.—Locality 3, unit 12; Locality 6, units 4 and 11; Locality 7, unit 9; Locality 8, units 5, 11, and 14; Locality 9, unit 3; Locality 10, units 6 and 8; Locality 13, unit 21; Locality 14, units 8 and 12.

Genus DIZYGOPLEURA Ulrich and Bassler, 1923

Type species: Dizygopleura swartzi Ulrich and Bassler, 1923, p. 314, by original designation.

Dizygopleura gibba Ulrich and Bassler, 1923
Pl. 5, figs. 17-21

Dizygopleura gibba Ulrich and Bassler, 1923, p. 684, pl. 59, fig. 25.

Remarks.—This species, which is very similar to *Dizygopleura swartzi* Ulrich and Bassler is distinguished from *D. swartzi* by its deeper S_1 and S_2, the weakness of the S_3, and the dorsal extension of L_3 and L_4 into a hump that varies in its prominence. As compared to the type specimens of *D. gibba* the specimens from the Mifflintown Formation have a slightly more sinuate ventral border and a less pronounced S_3. These features vary in the Mifflintown Formation specimens so that some are identical with the cotype specimens.

Occurrence.—Locality 9, units 3-5; Locality 13, units 18 and 20; Locality 14, unit 10; Locality 16, units 7 and 9; Locality 17, units 7 and 9.

Dizygopleura halli (Jones), 1890
Pl. 6, figs. 5-10

Beyrichia halli Jones, 1890, p. 15, pl. 4, fig. 21.
Kloedenella halli, Ulrich and Bassler, 1908, p. 319, fig. 62, pl. 43, fig. 4.
Dizygopleura halli, Ulrich and Bassler, 1923, p. 696, 697, pl. 62, fig. 24, 25.
Dizygopleura simulans Ulrich and Bassler, 1923, p. 698, pl. 62, fig. 28.
Dizygopleura subovata Ulrich and Bassler, 1923, p. 697, pl. 62, fig. 27.

Remarks.—The plesiotypes of *Dizygopleura halli* (Jones) figured by Ulrich and Bassler were examined and compared to the specimens obtained from the Bloomsburg and Wills Creek Formations. The type specimen of this species is probably in the British Museum and is not available. The length, shape, and definition of the sulci and lobes of the specimens are very similar and no significant difference can be seen between the plesiotypes and the Bloomsburg and Wills Creek Formations specimens. The only difference of note is that the area posterior to L_4 of the Bloomsburg and Wills Creek Formations specimens is somewhat wider than in the plesiotypes. This difference does not appear to be of importance.

Some of the Bloomsburg Formation specimens have a structure not seen on the plesiotypes. A few specimens bear a ventral sulcus that parallels the ventral border and extends from near the ventral ends of S_1 and S_3, but does not join with them.

The holotype specimens of *D. simulans* and *D. subovalis* were also examined in conjunction with the study of *D. halli* and it is the writer's opinion that these two forms are conspecific with *D. halli*. *D. subovalis* was distinguished by its more subovate outline and nonsinuate margin. This seems to be an individual difference. The figured holotype of *D. simulans* is

a very worn female carapace. Other specimens in the holotype slide of *D. simulans* are very similar to *D. halli* and are considered conspecific with it.

The cotypes of *D. simulans* var. *limbata* are missing from the U. S. National Museum so that no statements can be made about its affinities.

The variety *D. halli* var. *obscura* is raised to species status (see below).

The range of *D. halli* is subject to some speculation. It is not known precisely what formation the type specimen came from. On the basis of conversations with Dr. Jean M. Berdan of the U. S. Geological Survey it is suggested that the original specimen probably came from the Cobleskill Formation of New York. *D. halli* appears in the uppermost Bloomsburg Formation of Pennsylvania and in the Cedar Cliff Limestone Lentil of the Williamsport Member of the Wills Creek Formation and is present in the lower Wills Creek Formation. The range of this species thus would appear to be from upper Bloomsburg Formation to at least the Cobleskill Formation.

Occurrence.—Locality 4, units 2 and 4; Locality 5, unit 7; Locality 6, unit 2; Locality 8, unit 5; Locality 9, unit 1; Locality 10, unit 3; Locality 11, unit 1; Locality 12, unit 1; Locality 13, units 1 and 3; Locality 14, units 1 and 3; Locality 15, unit 1; Locality 18; Locality 19; Locality 20, unit 3.

DIZYGOPLEURA OBSCURA (Ulrich and Bassler), 1923

Not figured.

Dizygopleura halli var. *obscura* Ulrich and Bassler, 1923, p. 697, pl. 62, fig. 26.

Remarks.—In conjunction with the examination of the plesiotype specimens of *D. halli* the holotype specimen (USNM 63684) of the variety *obscura* was also examined. It was found to differ from *D. halli* by its short sulci that barely reach midheight and the relative weakness of the sulci and lobes as compared to *D. halli*. These differences are sufficient to warrant the raising of the variety to specific level.

Occurrence.—This species has been reported from the Tonoloway limestone of Maryland and West Virginia.

DIZYGOPLEURA PERRUGOSA Ulrich and Bassler, 1923

Pl. 6, figs. 1-4

Dizygopleura perrugosa Ulrich and Bassler, 1923, p. 700, pl. 60, fig. 26. Swartz, 1933, p. 248, 249, pl. 28, figs. 7 a-c, 8 a-c.

Occurrence.—Locality 9, unit 5; Locality 13, unit 8; Locality 14, units 9 and 10; Locality 16, unit 7.

DIZYGOPLEURA? PULCHELLA (Ulrich and Bassler), 1923
Pl. 6, figs. 11-15

Bollia pulchella Ulrich and Bassler, 1923, p. 513, pl. 37, figs. 26, 27.

Re-examination of the type material of this species showed that it is not a *Bollia* and that, moreover, the figures given by Ulrich and Bassler are in part the artist's conception and do not agree with the majority of the specimens on the type slab. Because this is a valid and distinctive species it is herein redescribed and refigured.

Description.—Outline subelliptical. Dorsal border straight. Posterior border evenly rounded. Ventral border slightly sinuate. Anterior border evenly rounded. Posterior cardinal angle very obtuse to absent.

S_1 very broad, semicircular, shallow, extends nearly to ventral margin, continues posteriorly as a narrow ventral sulcus. S_2 narrow, deep, straight, extends to about midheight. S_3 very broad, somewhat semicircular, shallow, extends nearly to ventral margin where it connects with ventral sulcus. Ventral sulcus narrow, shallow, ill defined on some specimens, extends from ventral ends of S_1 and S_3.

L_1 narrow, arcuate, slopes directly to anterior margin, parallels free edge and continues as a ventral ridge to join L_4. L_2 and L_3 narrow, low, straight, extend to about midheight, join below S_2 to form subquadrate platform that extends to ventral sulcus. L_4 narrow, arcuate, continues from ventral ridge to dorsal margin.

Ornamentation consists of punctae on S_1, S_3, ventral sulcus, and area posterior to L_4. Platform may or may not be punctate. Females distinguished from males by swelling of posterior areas. An average adult male measures length .94 mm., height .51 mm., width .36 mm.

Remarks.—Dizygopleura? pulchella is not definitely assigned to this genus because it does not have a hinge tooth. All other species of Dizygopleura, including the ones similar to *D.? pulchella* have a hinge tooth. Except for the absence of this feature the specimens assigned to this species answer the criteria for the genus *Dizygopleura.*

Dizygopleura punctella n. sp., *D. ventrisulcata* n. sp., and *D. reticulata* Swartz are all superficially similar to *D.? pulchella. D. punctella* is distinguished from *D.? pulchella* by the absence of a ventral sulcus, narrower sulci, more pronounced lobes, and the absence of punctation over the whole area posterior to L_4. *D. ventrisulcata* is very similar to *D.? pulchella* but differs in the absence of punctation posterior to L_4, in the presence of the dorsal junction of L_3 and L_4, and the constant presence of a nonpunctate platform below S_2. *D. reticulata* is perhaps closest to *D.? pulchella,* but can be differentiated from it on several points. L_1 of *D. reticulata* is broader, less well defined, and does not continue as a ventral ridge. S_1 of

D. reticulata is narrower and the platform below S_2 is always punctate.

As stated above, the original figures of Ulrich and Bassler, especially fig. 26, are in part erroneous. Fig. 26 shows L_2 and L_3 joined into a U shaped ridge with the ventral portion of the valve being punctate. No specimens on the type slab bear these exact features. Fig. 15, Plate 6 of the present paper reproduces photographically the specimens used by Ulrich and Bassler for their fig. 26. L_2 and L_3 join ventrally in a platform that is partially punctate in a few specimens on the type slab but L_2 and L_3 are not joined into a U shaped ridge.

The two other Wills Creek Formation species that were figured and described by Ulrich and Bassler as *Bollia* were also examined. They are *Bollia nitida* Ulrich and Bassler (1923, p. 513, pl. 37, fig. 25) and *Bollia immersa* Ulrich and Bassler (1923, p. 513, pl. 37, fig. 24). Neither of the type specimens of these species is sufficiently well preserved to be used for identification. *B. nitida* is nonpunctate although it is shown to be punctate in the figure of Ulrich and Bassler. *B. immersa* does not have a U-shaped ridge around the S_2 although one is shown in the figure by Ulrich and Bassler. Neither of the holotypes is a complete valve. Because the holotypes are so poorly preserved and because they may be conspecific with *D.? pulchella* it is suggested that they be considered *nomia dubia* until further specimens are found to substantiate or refute their specific status.

Occurrence.—Locality 10, unit 3; Locality 13, unit 3; Locality 14, unit 1; Locality 15, unit 1; Locality 19.

Dizygopleura punctella n. sp.
Pl. 6, figs. 16-24

Description.—Outline subelliptical. Dorsal border slightly arched. Posterior border rounded with slight swing. Posterior cardinal angle moderately obtuse. Ventral border straight to slightly sinuate. Anterior border evenly rounded. Right valve higher than left and slightly overlaps left valve posterior to hinge tooth. Left valve slightly overlaps right valve along ventral margin.

S_1 broad, deep, crescentic, extends from dorsal margin to near ventral margin where it narrows and turns posteriorly. In left valve S_1 produced into prominent hinge tooth. S_2 narrow, short, deep, extends from dorsal margin to near midheight. S_3 broad to narrow, deep, crescentic, originates just below dorsal margin and extends to near ventral margin where it narrows and turns anteriorly.

L_1 narrow, arcuate, originates just anterior to hinge tooth, extends nearly to ventral margin. L_2 short, narrow, straight, extends to near midheight. L_3 short, slightly broader than L_2, extends to midheight where it merges with the raised central and ventrocentral areas platform to which

L_2 is also joined. L_4 narrow, arcuate, originates near dorsal margin and extends to near ventral margin. In males L_4 stands prominently above posterior areas.

Females distinguished from males by swelling of posterior areas with concommitant loss of definition of L_4 and, in varying degrees, loss of S_3. S_1, S_3, and portions of male posterior areas closest to L_4 punctate. Posterior areas of females nonpunctate. Average size of adult male: length 1.15 mm., height .72 mm., width .47 mm.

Remarks.—This species is very common in the Bloomsburg Formation and in some samples is represented by several hundred specimens. It is estimated that in excess of 2,000 specimens have been observed. The examination of this large number of specimens has presented an excellent opportunity to observe individual variations from the "type" form. In some samples S_1 is very broad, in others it has narrowed slightly. In several samples the S_3 of the males is very narrow or almost absent, L_3 and L_4 having in part fused together. One characteristic that does not seem to vary is the position of the punctae.

D. punctella is allied to *D. reticulata* Swartz. *D. reticulata* is a punctate species bearing punctae in S_1, S_2, the posterior areas, and the areas below S_2. *D. punctella* has no punctae on the surfaces below S_2, and the lobes are higher and more pronounced than in *D. reticulata.*

Occurrence.—Locality 2, unit 8; Locality 3, units 6, 8, 10, 12-14; Locality 4, units 4 and 5; Locality 5, units 7, 9, 11, 12, and 15; Locality 6, units 4 and 11; Locality 7, unit 6; Locality 8, units 11, 13-15, and 17; Locality 9, units 3 and 5; Locality 10, units 3, 4, and 6-8; Locality 11, units 5 and 9; Locality 13, units 8, 20, and 21; Locality 14, units 8 and 12; Locality 17, unit 7.

Types.—Holotype, a male carapace, USNM 143213; Paratypes, 5 male carapaces, USNM 143214a, 143214b, 143214c, 143214d, 143214e, and 3 female carapaces, USNM 143215a, 143215b, 143215c.

Dizygopleura swartzi Ulrich and Bassler, 1923
Pl. 7, figs. 1-5

Dizygopleura swartzi Ulrich and Bassler, 1923, p. 693, pl. 62, figs. 1-8. Swartz, 1933, p. 245-247, Text Fig. 1 (6a, 6b), pl. 28, figs. 3 a-g, 4 a-g. *Dizygopleura acuminata* Ulrich and Bassler, 1923, p. 685, pl. 60, figs. 4-9.

Remarks.—This species was adequately redefined by Swartz (1933) from material obtained from the middle member of the Mifflintown Formation of Pennsylvania. The material figured in the present paper was collected from the same general horizon at Pinto, Maryland cited by Ulrich and Bassler in their original description; the material agrees closely with the type specimens.

Occurrence.—Locality 7, unit 7.

DIZYGOPLEURA UNIPUNCTATA Ulrich and Bassler, 1923
Pl. 7, figs. 6-10

Dizygopleura unipunctata Ulrich and Bassler, 1923, p. 699-700, pl. 60, fig. 25.

Remarks.—Examination of the type specimen, a left valve, shows that the few specimens from the Mifflintown Formation are conspecific with it. The diagnostic feature of this species that separates it from allied species is a small pit directly below S_2 near the ventral margin. This pit is very shallow and hard to see and is falsely accentuated in the Ulrich and Bassler Figures. The specimens from the Mifflintown Formation have a small depression under S_2 of the same size and shape as the depression on the holotype.

The right valve of this species has not been previously figured. It differs from the left valve by the dorsal projection of L_3 above the hinge line and the near absence of the ventral pit.

The Mifflintown specimens differ from the holotype in possessing a concave posterior slope from L_4 to the posterior margin. The posterior slope in the holotype is nearly straight. One specimen from the Mifflintown Formation was found that has a slightly convex slope from L_4 to the posterior margin. This is considered to be the female dimorph. Because the posterior slope of the holotype is nearly that of the female specimen the holotype is also considered to be a female.

Occurrence.—Locality 16, unit 7; Locality 17, unit 7.

DIZYGOPLEURA VENTRISULCATA n. sp.
Pl. 7, figs. 11-18

Description.—Outline subelliptical. Dorsal border slightly rounded. Posterior border rounded with slight swing. Posterior cardinal angle 90° to moderately obtuse. Ventral border straight to slightly sinuate. Anterior border evenly rounded.

S_1 broad, deep, crescentic, dorsally extends into small hinge tooth on left valve, extends from dorsal margin to about one-sixth of height from ventral margin where it turns posteriorly and continues as a ventral sulcus. S_2 deep, narrow, straight, extends to near midheight. S_3 broad, deep, crescentic, originates just below dorsal margin and extends to about one-sixth of height from ventral margin where it narrows and turns anteriorly to join the ventral sulcus. Ventral sulcus narrow, parallels ventral margin.

L_1 narrow, arcuate, extends from dorsal margin just anterior to hinge tooth to near ventral margin where it continues posteriorly as ventral ridge. L_2 and L_3 narrow, extend to about midheight, joined in ventrocentral area in a platform raised above sulci bases. L_4 narrow, high, arcuate, dorsally joined to L_3, ventrally joined to ventral ridge, in males stands

prominently above posterior areas. Ventral ridge narrow, low, lowest in region just below S_2. In dorsal view of complete specimens the junction of L_3 and L_4 produce a triangular shaped, flat area that extends to just posterior of hinge tooth.

Females distinguished from males by swelling of posterior areas and concommitant loss of definition of L_4. S_1 and S_3 in some specimens floored with very fine punctae, some specimens have no punctae. Average size of adult male: length .94 mm., height .55 mm., width .40 mm.

Remarks.—*D. ventrisulcata* is similar to *D. punctella* n. sp. and *D. hymenifera* Swartz. *D. ventrisulcata* is differentiated from both of these species by the possession of a ventral sulcus and ridge. *D. punctella* has no such sulcus and ridge and *D. hymenifera* has only the faintest suggestion of a ventral sulcus. *D. punctella* does not have the L_3 and L_4 joined and the L_4 of *D. hymenifera* is relatively further from the posterior margin than in *D. ventrisulcata.*

Occurrence.—Locality 4, unit 4; Locality 5, units 7 and 12; Locality 6, units 4 and 6; Locality 8, units 11 and 13; Locality 9, unit 3; Locality 12, unit 6; Locality 14, unit 9; Locality 20, unit 3.

Types.—Holotype, a male carapace, USNM 143216; Paratypes, 3 male carapaces, USNM 143217a, 143217b, 143217c, 4 female carapaces, USNM 143218a, 143218b, 143218c, 143218d.

Superfamily LEPERDITICAEA
Family LEPERDITIIDAE Jones
Subfamily LEPERDITIINAE Jones
Genus HERRMANNINA Kegel, 1933

Type species: Herrmanella waldschmidti Paeckleman, 1922.

HERRMANNINA WILLSENSIS (Ulrich and Bassler), 1923
Pl. 7, fig. 24

Leperditia elongata var. *willsensis* Ulrich and Bassler, 1923, p. 500, pl. 36, figs. 3-6.

Herrmannina willsensis, Swartz, 1949, p. 315, pl. 66, figs. 11, 12.

Remarks.—The few complete leperditid valves found in the Bloomsburg Formation conform to the characteristics of this species. One poorly preserved specimen was found that showed a denticulate hinge.

Occurrence.—Locality 8, units 5 and 13; Locality 9, unit 3; Locality 19.

HERRMANNINA species
Not figured.

Remarks.—Most of the recovered specimens of *Herrmannina* are very fragmentary. This is in part the result of the preparation methods, but probably is in most part the result of preburial movement which has broken

the specimens. It is most probable that many of the specimens called *H.* sp. are actually *H. willsensis.*

Occurrence.—Locality 2, units 7 and 8; Locality 3, units 6, 8, 10, and 12; Locality 4, units 4 and 5; Locality 5, units 7 and 11; Locality 6, units 4, 6, and 11; Locality 7, units 5 and 9; Locality 8, units 4, 11, 13, 15, and 17; Locality 9, units 3-5; Locality 10, units 3, 4, and 6; Locality 11, units 1 and 9; Locality 12, units 6, 7, and 10; Locality 13, units 1, 3, 8, 10, and 21; Locality 14, units 1, 8, 9, and 12; Locality 15, unit 12; Locality 16, unit 8; Locality 18; Locality 20, unit 3.

Suborder PODOCOPA
Superfamily CYPRIDACEA
Family BAIRDIIDAE Sars
Genus BYTHOCYPRIS Brady, 1880

Type species: Bairdia bosquetiana Brady, 1866, p. 364.

Remarks.—*Bythocypris* was based on Recent species. It is somewhat doubtful that the Silurian species assigned to it are truly congeneric with it. Until closer examination of the internal characteristics of the Silurian species is made their generic affinities are considered in doubt and the generic name is placed in quotes to imply their doubtful assignment.

"BYTHOCYPRIS" PHILIPSIANA (Jones and Holl), 1869
Pl. 7, figs. 19-21

Bythocypris philipsiana, Ulrich and Bassler, 1923, p. 702, pl. 63, fig. 9. For an extensive synonomy of this species see Bassler and Kellett, 1934, p. 231-232.

Remarks.—The specimens from the Bloomsburg and Mifflintown Formations agree in all external respects with the material collected and described by Ulrich and Bassler. A few valves have been found that show the interiors. Both valves interiors bear a noticeable low ridge in the anterodorsal region. This ridge has no external expression. Presumably this ridge was a position of muscle attachment.

Occurrence.—Locality 6, units 6 and 11; Locality 7, unit 6; Locality 8, units 14 and 15; Locality 11, units 5 and 6; Locality 13, unit 18; Locality 14, units 9 and 10; Locality 15, unit 12; Locality 16, unit 7.

"BYTHOCYPRIS" cf. "B." PERGRACILIS Ulrich and Bassler, 1923
Pl. 7, figs. 22, 23

(cf.) *Bythocypris pergracilis* Ulrich and Bassler, 1923, p. 703, pl. 63, figs. 3, 4.

Remarks.—Some samples from the Bloomsburg Formation contain an ostracod that is similar to *B. pergracilis.* The specimens are somewhat poor-

ly preserved and the overlap is not definitely known. Thus these specimens can only be referred to this species.

Occurrence.—Locality 6, unit 4; Locality 8, units 11 and 13.

Phylum ECHINODERMATA
Class CRINOIDEA
Crinoid columnals
Not figured.

Occurrence.—Crinoid columnals are a very rare fossil in the red beds of the Bloomsburg Formation. They are found at Locality 8, units 13 and 14; Locality 9, unit 3; Locality 14, units 9 and 10.

Phylum CHORDATA
Class AGNATHA
Order HETEROSTRACI
"Fish Scales"
Pl. 7, fig. 27

Remarks.—Six localities that expose the Bloomsburg Formation have produced scales of one or more heterostracid fishes. The scales are never large and are apparently broken portions of larger head shields or scales.

Beerbower and Hait (1959, p. 198-203) discuss the discovery in the Bloomsburg Formation at Delaware Water Gap of fish scales and head shields referable to *Archegonaspis van ingeni*. Material was collected by the present writer from their Locality 4 (*ibid.*, p. 199) to compare with the scales obtained from the Bloomsburg Formation of central Pennsylvania. The only distinction noted is that the dentine ridges of the scales collected at Delaware Water Gap are one-third the width of the ones collected from central Pennsylvania. It may be that these scales represent more than one species of fish. The scales from the Bloomsburg Formation of central Pennsylvania are identical with the ones mentioned by Leutze (1960, p. 215) which he collected from a few feet above the top of the Bloomsburg Formation at Round Top, Maryland. Comparative specimens were also collected from Round Top by the writer.

Occurrence.—Locality 6, unit 2; Locality 8, unit 5; Locality 12, units 1 and 9; Locality 13, units 1, 3, 8, and 14; Locality 14, unit 1; Locality 15, unit 1.

?AGNATHID scales
Pl. 7, figs. 25, 26

Remarks.—A small fossil has been found in several samples from the Bloomsburg Formation whose identity is in doubt. The fossil is composed of a dark, organic-looking material similar to the heterostracid fish scales. The fossil consists of a shield shaped portion, moderately convex, with an

"umbonal" apex. The edges of the "shield" are serrated or ridged. The "shield" is mounted onto a nondescript plate of the same material by a very short column of slightly less diameter than the "shield."

Occurrence.—Locality 3, units 10 and 13; Locality 4, unit 5; Locality 5, unit 12; Locality 6, units 4 and 11; Locality 8, units 13 and 17; Locality 9, unit 3; Locality 11, units 5 and 9; Locality 12, unit 14; Locality 13, unit 20; Locality 14, unit 12; Locality 15, units 10 and 12; Locality 17, unit 8.

THE SIGNIFICANCE OF FOSSILIFEROUS RED BEDS

General statement

Red beds have occupied the attention of geologists for many years. The attention these rocks have received is largely due to their striking color and the many theories that have been offered to explain their origin. Early opinions that red beds indicated an arid or semiarid environment were based on the association of red beds with evaporites. However, most arid regions were observed to be other than red colored and the simple early explanation was proved not valid. Recent investigations (Krynine, 1949; Van Houten, 1948) have shown that complex factors as the type of source area and its environment, and the environment of the depositional area all play a role in the production of red beds.

The Bloomsburg Formation seems to be a typical red bed deposit, differing from some other red beds by containing fossils. Examination of the lithologic and paleontologic data on the Bloomsburg Formation allows certain conclusions to be drawn concerning the origin of these particular red beds. Comparison may then be made between the assumed origin of the Bloomsburg Formation and the generally accepted theories on the origin of other red beds.

Other fossiliferous red beds

The Bloomsburg Formation is by no means unique in containing fossiliferous red beds. The Ordovician Mocassin and Sequatchie Formations of Virginia contain fossils in intercalated marine sediments and rarely in the red beds. Bates (1939, p. 56) lists brachiopods and bryozoa from the Sequatchie, but not from the red beds. Butts (1933, p. 18, 19, 23; 1940, p. 179-191, 221-229) lists a few fossils in both the Mocassin and Sequatchie Formations, but he generally does not state in what lithology they were found. Cooper (1944, p. 105) lists bryozoans, brachiopods, pelecypods, gastropods, and cephalopods from red and green siltstones of the Maysville division of the Ordovician Martinsburg Formation of Virginia. Schuchert (1941, p. 313-318) gives four stratigraphic sections of the Lower Silurian Cabot Head Shale in Ontario Province in which he lists

abundant bryozoans, brachiopods, and other fossils from the red limestones and shales. Benson (1955, p. 1032) studying the Missippian Fern Glen Formation found that "The ostracods of the Fern Glen at the type locality seem to be concentrated mainly in the red shale, . . . " Echols and Jung (1956) also found fossils in the red beds of the Fern Glen Formation. Walter (1959, p. 1070) lists seven genera of brachiopods found in a 20 foot red unit in the Pennsylvanian Minturn Formation of Colorado. He concludes that this red bed is marine in origin and represents a large volume of hematite deposited rapidly in an actively subsiding basin where the reducing capacity was low.

Most of these cited red beds are thin units or are intercalated within more normally marine sediments; they presumably represent relatively short periods of red-bed deposition alternating with deposition of other types of sediments. Much of the Bloomsburg Formation differs from these red beds in that the fossils are primarily associated with red beds without intercalated marine beds. The Bloomsburg Formation also appears to represent continuous deposition of muds over longer periods of time under relatively uniform environmental conditions.

Origin of red beds

Many papers have been written on the origin of red beds. Two of these (Krynine, 1949; Van Houten, 1948) review and examine the various theories applied to the origin of red beds. The reader is referred to these papers for extended discussions on the origin of red beds.

The color of red beds has been attributed to several processes, five of which are known to have produced red bed deposits. These are:

1. The color is inherited from pre-existing red beds by erosion and redeposition without reduction or hydration of the iron.
2. The color is derived from red-colored residual soils forming in well-drained uplands with a humid tropical or subtropical climate.
3. The color results from oxidation or dehydration of iron compounds at the site of deposition.
4. The color results from dehydration of ferric oxide by deep burial.
5. The color results from oxidation of ferrous compounds, after exposure.

At least a few red-bed units in the geologic column can be attributed to each one of these processes. However, it is the consensus of many authors that most red beds have been formed by the second and third processes, and that the others are of minor importance.

Miller and Folk, (1955, p. 344) believe that an oxidizing environment at the site of deposition is the most prevalent cause of red beds. Their

evidence is primarily that in red-bed thin sections, hematite does not coat sand grains at points of contact. They argue that pre-existing hematite should cover all sand grains that were being transported; that grains not covered with hematite are found is evidence to them that the hematite must not be predepositional. However, it is to be expected that abrasion during transportation would tend to clean off the sand grain surfaces. It is also more logical to assume that pre-existing hematite would be, for the most part carried in the clay size fraction rather than on the sand grains. Dunbar and Rodgers (1957, p. 211) note that in many red beds the hematite is concentrated in the fine fraction.

It may be true that the sandstones Folk examined from the Rose Hill Formation of West Virginia (Miller and Folk, 1955, p. 334) are the result of hematite forming at the site of deposition. These sandstones have also been examined several times by the present writer. They are considerably different in color and appearance than the usual red beds of the Bloomsburg, Catskill, and Mauch Chunk Formations of Pennsylvania and probably required a different depositional environment.

Miller and Folk (1955, p. 339) state that the presence of detrital magnetite and ilmenite in all the red-bed thin sections they observed indicates that the source area for all red beds must have been a metamorphic or igneous terrane. They feel that the source area of these sediments is the most important factor in the production of red beds.

However, an igneous or metamorphic terrane may be the source area of both red and nonred sediments; the distinguishing feature between these sediments is their color, not their source area. The climatic and other physicochemical conditions that allow hematite to remain as hematite in sediments or allow it to be formed in soils or sediments are equally as important factors in the formation of red beds as is the source area.

Krynine (1950, p. 143-152) estimates that 90% of existing red beds are the result of development of red residual soils in warm, humid uplands which are subsequently eroded and transported to the depositional site without reduction or hydration of the hematite. Krynine (1949, p. 63) also feels that these primary red beds are, in general, continental deposits. However, the Bloomsburg red beds, or at least the fossiliferous portion of these red beds, most probably are not continental. The fossiliferous nature of the rocks indicates that they were deposited subaqueously and thus were not exposed to sub-aerial oxidation after deposition, supporting a predepositional origin of the ferric compounds rather than postdepositional.

However, the Bloomsburg red beds were deposited in a subaqueous environment where, according to Krynine (1944, p. 62), there is a deficiency of oxygen and the general conditions are reducing, especially if appre-

ciable amounts of organic material are present. The preservation of the ferric compounds in this environment requires either rapid deposition so that reduction cannot take place at the sedimentary interface, or presence of such small amounts of organic material that the little oxygen present in the water could oxidize it without the organic material reducing the iron; possibly a combination of the two factors existed. Outside the fossiliferous area it is entirely possible that many of the red beds were deposited terrestrially so that exposure to air oxidized the included organic material and the ferric compounds were left in the oxidized state and buried as such.

Krynine (1950) has presented data to show that red soils are forming in warm, humid, well-drained upland areas. Dunbar and Rodgers (1957, p. 216) note that red muds are deposited off the mouth of the Amazon River in such quantities that it cannot be reduced. Thus all the factors which are assumed to have operated to form the Bloomsburg Formation are known to be operating today.

Microfossils as paleoecological indicators

Microfossils by their very nature of being small are subject to transportation by currents more so than other fossils. Jones (1956, p. 259) notes that "widespread geographical distribution of microfossils into a variety of environments within short vertical ranges renders such fossils valuable for stratigraphic correlation, but they are seldom of value in paleoecological reconstruction." Van Voorthuysen (1960, p. 293), in summarizing the ecological implications of a study of the Ems estuary, noted that of 36 ostracod species found, only 8 live in the estuary and the other 28 were transported after death from the open reaches of the North Sea. He concludes (*ibid.*, p. 294) "From the above it follows that in an ancient littoral-lagoonal environment, the possibility must be considered that a portion of the foraminifer and ostracod fauna was washed in from another ecological zone, however, the macrofauna, in general, will be found in place" (auth. trans.).

Preburial movement of the Bloomsburg fossils is a factor to be considered and is indicated by the following data: Many of the macrofauna elements, as the brachiopods, are fragmental and poorly preserved; This may in part be due to preparation procedures, the original character of the shell, and the inherent poorness of preservation in an argillaceous sediment. It is almost certainly the result, in part, of some preburial movement. Considering the microfauna, specifically the ostracods which make up the great bulk of the fauna, the best evidence for movement is that there is a nearly total lack of the earlier instars. All the life stages would be expected if the ostracods died where they lived. The ostracods also are not as well preserved as ones found in limestone.

Notwithstanding the fact that microfossils are easily transported, and the Bloomsburg forms are no exception to the rule, certain conclusions may be drawn from these microfossils if care is exercised. Considering all the data present, paleontologic (both macro- and microfossil) and lithologic, it is believed that a reasonably accurate account can be drawn even if it must be in generalities.

Depositional history of the Bloomsburg Formation

Microscopic examination of the lithologies of the Bloomsburg Formation indicates that the terrane from which the red beds were derived was composed both of metamorphic and igneous rocks. The metamorphic terrane is indicated by the presence of schistose fragments and the igneous terrane by fragments with a myrmekitic texture. The accessory minerals are also indicative of a metamorphic and igneous provenance.

The fossils in the Bloomsburg Formation indicate that the sediments were deposited subaqueously and were not exposed to air. Lithologic features such as cross bedding, heterogeneity of sediment size, and channeling that would indicate an alluvial origin of the rocks are absent in the fossiliferous areas. Thus the red color of these rocks most probably formed predepositionally and not by post-depositional oxidation. It is possible however, that some of the non-fossiliferous sandstones and siltstones are continental in origin and that their red color was formed post-depositionally. However, these rocks differ little from the fossiliferous rocks and it is felt that the suggested pre-depositional origin applies to both the unfossiliferous and fossiliferous rocks.

Deposition of the Bloomsburg sediments was probably rapid. Rapid deposition is indicated by the unsorted and clayey nature of the sandstones which indicates that currents did not have time for reworking and winnowing out the finer material. The local Bridgeport sandstone is an exception. It represents clean unsorted sands that must have been reworked to remove the clay and hematite, and it may well have formed on a bar or beach. Rapid deposition is also necessary to explain the retention of the red color which under normal subaqueous circumstances would be reduced to a nonred color. The lack of the subaqueous reduction of the red beds may have been partly due to an absence of sufficient organic material necessary to the reducing conditions.

The character of the fauna indicates that the animals lived in water that was probably brackish rather than fresh or of normal marine salinity. All major fossil phyla, excluding the Porifera, are found, though most of these phyla are represented by only a few specimens. Only one coral has been found in the red beds. The pelecypods, gastropods, and crinoids are

represented by less than 10 specimens from all the outcrops examined. The foraminifers, bryozoans, brachiopods (excluding *Lingula* sp.), and fish scales are found in several samples but are not truly common. Only the ostracods are numerous in the red beds.

Ostracods, as observed in living forms, can exist in environments ranging from marine to fresh water. Because some of the Bloomsburg ostracods are also found in normal marine sediments it is assumed that the ostracods of the Bloomsburg waters lived in an at least partly saline environment. That the waters were not truly marine is shown by the relative lack of other members of the invertebrate fauna that could exist under normal saline conditions. Also the ostracod fauna is marked by large numbers of individuals but low numbers of species. Present day brackish faunas are characterized by few species and large numbers of individuals, whereas marine waters are usually marked by large numbers of species.

It is possible that some elements of the fauna may be from different environments but there does not seem to be any appreciable mixing of differing environmental elements. Thus the fauna has the over-all aspect of one developed in brackish water. It is uncertain why the pelecypods are not more abundant, as in present day brackish water faunas, unless they were prevented from establishing themselves by turbid waters.

Because it is certain that the fossils have been moved an undetermined amount prior to burial it is impossible to definitely state the salinity of the water in which the fossils were deposited. However, it is the opinion of the writer that the waters of deposition were, in general, brackish. This opinion is based on the fact that there is a scarcity of the normal marine macrofauna that would be expected if the depositional waters were marine. A fresh water or alluvial origin is excluded for the fossiliferous red beds on the absence of sedimentary characteristics and lithologies of continental and alluvial deposits. Thus it appears that while the place of life and place of burial were not the same for most of the fossils the salinity in both cases was probably brackish.

The depth of the water into which the red muds were poured is assumed to have been less than 90 feet. Elias (1937) discusses the depth at which animals are found today, and observed that *Lingula* is found usually from 30 to 60 feet below water level; ostracods are common down to 90 feet. Both these fossil forms are common in the Bloomsburg and thus the depth of deposition would be expected to fall in this range if the fact that the fossils were transported is minimized.

It is probable that the Bloomsburg Formation is continuous with the Vernon Formation of New York. These red beds may also have continued into Canada and connected with the red beds of the Pte. aux Chenes Formation of northern Michigan. This great extent of red beds suggests that

the climatic conditions necessary for the production of red soils were present over a large metamorphic and igneous area in the Middle Silurian and that large quantities of red muds were deposited by several large river systems. These deposits coalesced to form the Bloomsburg and Vernon Formations, and possibly the Pte. aux Chenes Formation as well.

In general the writer agrees with Swartz (1946, p. 27) as to the probable conditions of deposition of the Bloomsburg Formation. Swartz indicated that the exposures in eastern Pennsylvania represent alluvial deposits and that the claystones, siltstones and sandstones of central Pennsylvania were deposited in broad lagoons. He stated "the silty sandstones are too regular and extensive to be direct deposits of river waters; and though retaining their red color were evidently spread by currents of a broad, shallow, freshened, lagoonal region." Swartz also stated that the Bloomsburg Formation was "the deposits of a great river system that emerged in the general latitude of northern New Jersey, . . . "

In the opinion of the present writer the red muds were brought in by many streams that drained a humid, warm, metamorphic and igneous highland upon which red soils had been produced. Because much of the red beds that presumably were to the southeast of the present known exposures have been eroded away it is impossible to determine how many river systems carried the red sediment. The writer believes that to account for the great extent of red beds from Virginia to New York and possibly into Michigan many streams were necessary to carry the sediment. Many of the coarser rocks may represent alluvial deposits, particularly those which show "channel" sands. Deposition must have been rapid to prevent reduction of the red mud in the shallow brackish waters that supported the limited fauna. Whether the waters were lagoonal or not is indeterminable, but their salinity was probably low. This may have been caused by offshore bars with brackish lagoons, lack of tidal currents to bring in saline waters, or dilution by fresh water from the rivers.

These ideas on the origin of the Bloomsburg Formation then are but a modification of the most generally accepted theory on the origin of red beds and answer the most important questions of how the red coloring matter was formed and retained after deposition.

CORRELATION

The faunal evidence obtained from the Bloomsburg Formation is of such a nature that only general statements can be made about the time equivalence of the various portions and contiguous units. Most of the correlations that have been previously drawn (Swartz and Swartz, 1931;

Swartz, 1934 and 1939) are essentially correct. The paleontologic data from the present study add their weight to these correlations.

Of the seven common or very common ostracod species found in the red beds, only three are restricted to a relatively short stratigraphic range. One is *Dizygopleura halli* (Jones) which, with two exceptions, is found only above the Moyer Ridge Member of the Bloomsburg Formation of central Pennsylvania. The two exceptions are in the Lewisburg section (Locality 4, unit 4) and in the Selinsgrove section (Locality 5, unit 7) where this species was found in samples taken roughly 20 feet below the base of the Moyer Ridge Member. The other restricted species are *Kloedenella gibberosa* Ulrich and Bassler, and *Velibeyrichia mesleri* (Ulrich and Bassler) which are restricted to the middle portion of the Bloomsburg Formation. A small variety of *K. gibberosa* is found in the lower Bloomsburg at a few localities.

The other four common species range throughout much of the red beds. Of these *Eukloedenella* sp. and *Herrmannina* sp. are of little stratigraphic use. *Kloedenia normalis* Ulrich and Bassler is a wide ranging species found in many types of sediments from marine limestones to the red beds and over a stratigraphic range exceeding the limits of the Bloomsburg Formation. *Dizygopleura punctella* n. sp. is restricted to the red beds but ranges from near the base to below the Moyer Ridge Member of the Bloomsburg Formation.

Of the rare or very rare species found in the red beds most are found in the middle of the Bloomsburg Formation and together with *Kloedenella gibberosa* and *Velibeyrichia mesleri* suggest correlation of this portion of the red beds with the upper member of the Mifflintown Formation. A few of the rare species not found near the middle of the Bloomsburg Formation are discussed below.

Pseudobeyrichia simplex n. sp. is restricted to the Bloomsburg Formation and has been found 100 to 150 feet below the top. It has been found in only 6 samples and is of little correlative value.

Bolbiprimitia subaequata (Ulrich and Bassler) is found most often associated with *Dizygopleura halli* near the top of the red beds. It has also been found in a few samples in the middle portion of the red beds. This species is therefore not too trustworthy for fine correlation.

Kloedenella cristata n. sp. and *Dizygopleura ventrisulcata* n. sp. are generally associated with each other and are most commonly found from 85 to 150 feet below the top of the red beds, at the base of the Moyer Ridge Member. At two localities *D. ventrisulcata* has been found as much as 230 feet below the top.

No well defined faunal zones can be established within the Bloomsburg Formation. The zones mentioned by Swartz (1934, p. 122, 124, 125, fig.

2, 3) Zone 18, the *Kloedenella gibberosa* zone, and Zone 19, the upper *Dizygopleura swartzi* zone, are not considered true zones because nowhere have they been accurately defined as to content and actual stratigraphic range; also the upper and lower boundaries of these zones have not been determined. On the basis of the data obtained from this present study the top of the *K. gibberosa* zone, defined as the upper range of this species, is located at the base of the Moyer Ridge Member of the Bloomsburg Formation of central Pennsylvania and at the base of the Williamsport Member in the region south from Cumberland, Md. The range of *Dizygopleura swartzi* is probably nearly the same as *K. gibberosa,* therefore Zone 19 may be discarded.

It might be advisable to establish a new faunal zone including the Williamsport Member, the portion of the Bloomsburg Formation from the base of the Moyer Ridge Member upward, and including higher stratigraphic units than these. It is suggested that *Dizygopleura halli* (Jones) which appears in the Williamsport Member and in the claystones just above the Moyer Ridge Member of the Bloomsburg is suitable for the zonal name. The full extent of this zone is not known at this time, for only the base can be defined. *D. halli* is known to range through the Wills Creek Formation and possibly into the Cobleskill Formation. It is probable that these zones—that of *K. gibberosa* and *D. halli*—have only limited value and should be used for correlation in local areas. Further work is necessary to establish the full extent and content of these zones, if, indeed, they can be called zones.

The most distinctive and important faunal change in the Bloomsburg Formation occurs just below the Moyer Ridge Member. Most of the ostracods, excluding *Kloedenia normalis,* found below the Moyer Ridge Member of the Bloomsburg Formation are not found above it. This faunal change is found at all the exposures sampled. This evidence, admittedly, is not conclusive, but it is the opinion of the writer that the Moyer Ridge Member of the Bloomsburg Formation represents a nearly isochronous deposit, correlative with the Williamsport Member of the Wills Creek Formation.

No faunal evidence is available to correlate the Bloomsburg Formation of central Pennsylvania with the thick deposits in eastern Pennsylvania, except for the fish fossils found at Delaware Water Gap and in central Pennsylvania, and it is doubtful that the fossils of the two areas are conspecific. It is likely that the occurrence of the heterostracid remains above the Moyer Ridge Member of the Bloomsburg Formation in central Pennsylvania and at Delaware Water Gap represents similar environmental conditions, but whether they have time-comparative significance is not known.

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EXPLANATION OF PLATES 1-7

Methods used in making the photographs have been discussed under Preparation. Where a pair of photographs have been used to make a stereograph only the left-hand element is numbered.

EXPLANATION OF PLATE 1

All figures X 15 unless otherwise indicated

Page

Figure *1, 2—Lagenammina* cf. *L. cornuta* Grubbs. Side and top views of two tests, from the Bloomsburg Formation, Locality 9. X 20 70

3, 4—Lagenammina cf. *L. stilla* Moreman. Side views of two tests, from the Bloomsburg Formation, Locality 9. X 20 70

5—Bathysiphon cf. *B. exiguus* Moreman. Side view of a test from the Bloomsburg Formation, Locality 9. X 20 69

6-8—Paraechmina depressa Ulrich and Bassler. *6, 8,* lateral and ventral views of left valve; *7,* lateral view of right valve. From the upper member of the Mifflintown Formation, Locality 14. X 20 73

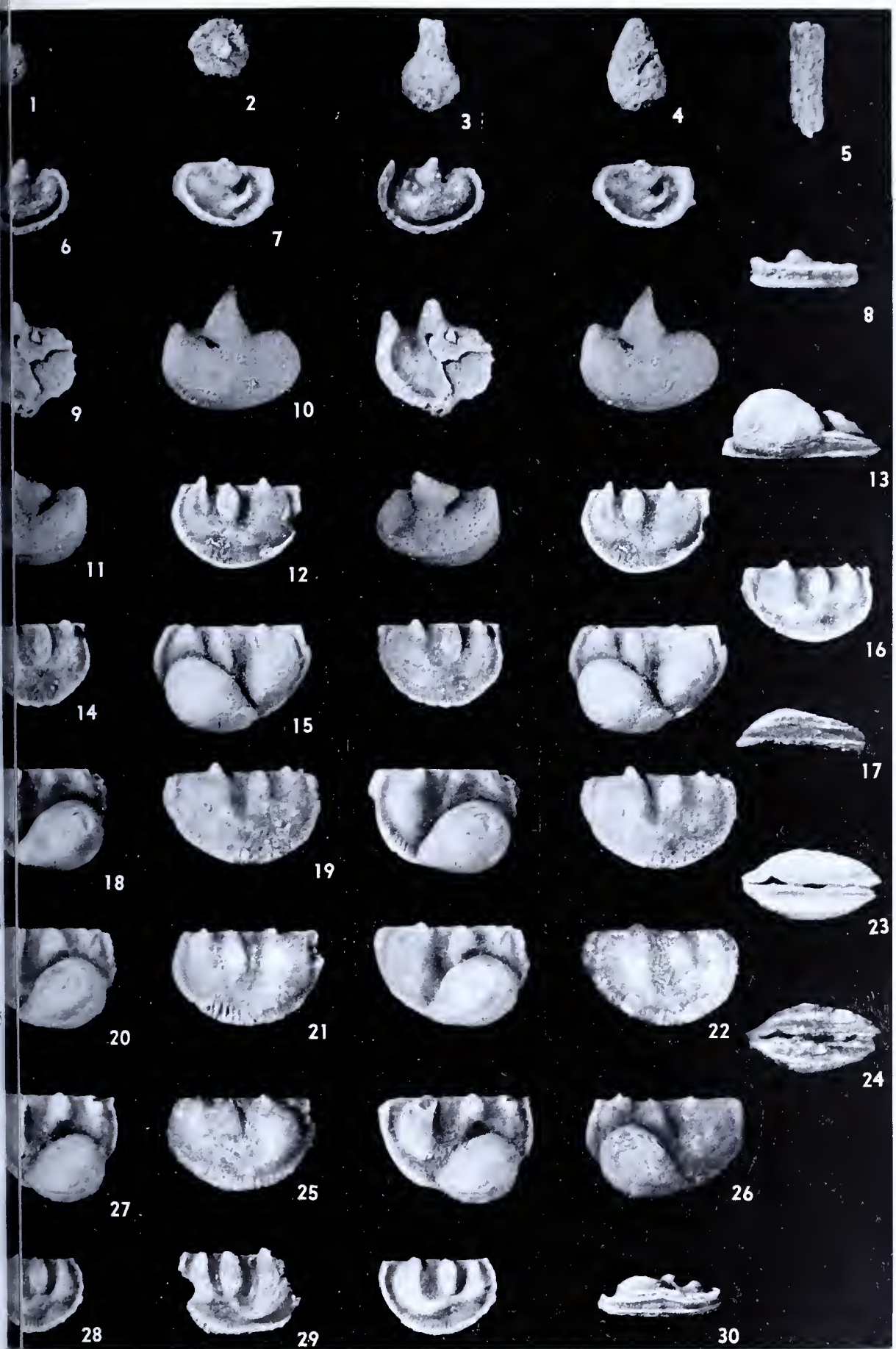
9—Paraechmina inaequalis Ulrich and Bassler. Lateral view of partial left valve from the Bloomsburg Formation, Locality 9. X 20 73

10, 11—Paraechmina postica Ulrich and Bassler. Lateral views of left and right valves from the upper member of the Mifflintown Formation, Locality 14 73

12-18—Velibeyrichia mesleri (Ulrich and Bassler). *12,* lateral view of male left valve; *13, 15,* ventral and lateral views of female left valve; *14, 17,* lateral and ventral views of male right valve; *16,* lateral view of male right valve; *18,* lateral view of female right valve. From the upper member of the Mifflintown Formation, Locality 14 74

19-26—Velibeyrichia tricornia n. sp. *19, 22,* lateral views of male right valve, holotype, USNM 143201, *22* uncoated to show more of the velate frill; *20,* lateral view of female right valve, paratype, USNM 143202a; *21, 25,* lateral views of male left valve, paratype, USNM 143202c, *25* uncoated to show the velate frill; *23, 24,* ventral views of male left and right valves artificially joined, paratype, USNM 143202d, *24* uncoated to show more of velate frill; *26,* lateral view of female left valve, paratype, USNM 143202b. From the upper member of the Mifflintown Formation, Locality 16 74

27-30—Velibeyrichia waldronensis (Ulrich and Bassler). *27,* lateral view of female right valve; *28, 30,* lateral and ventral views of male right valve; *29,* lateral view of partial male left valve. From the upper member of the Mifflintown Formation, Locality 14 75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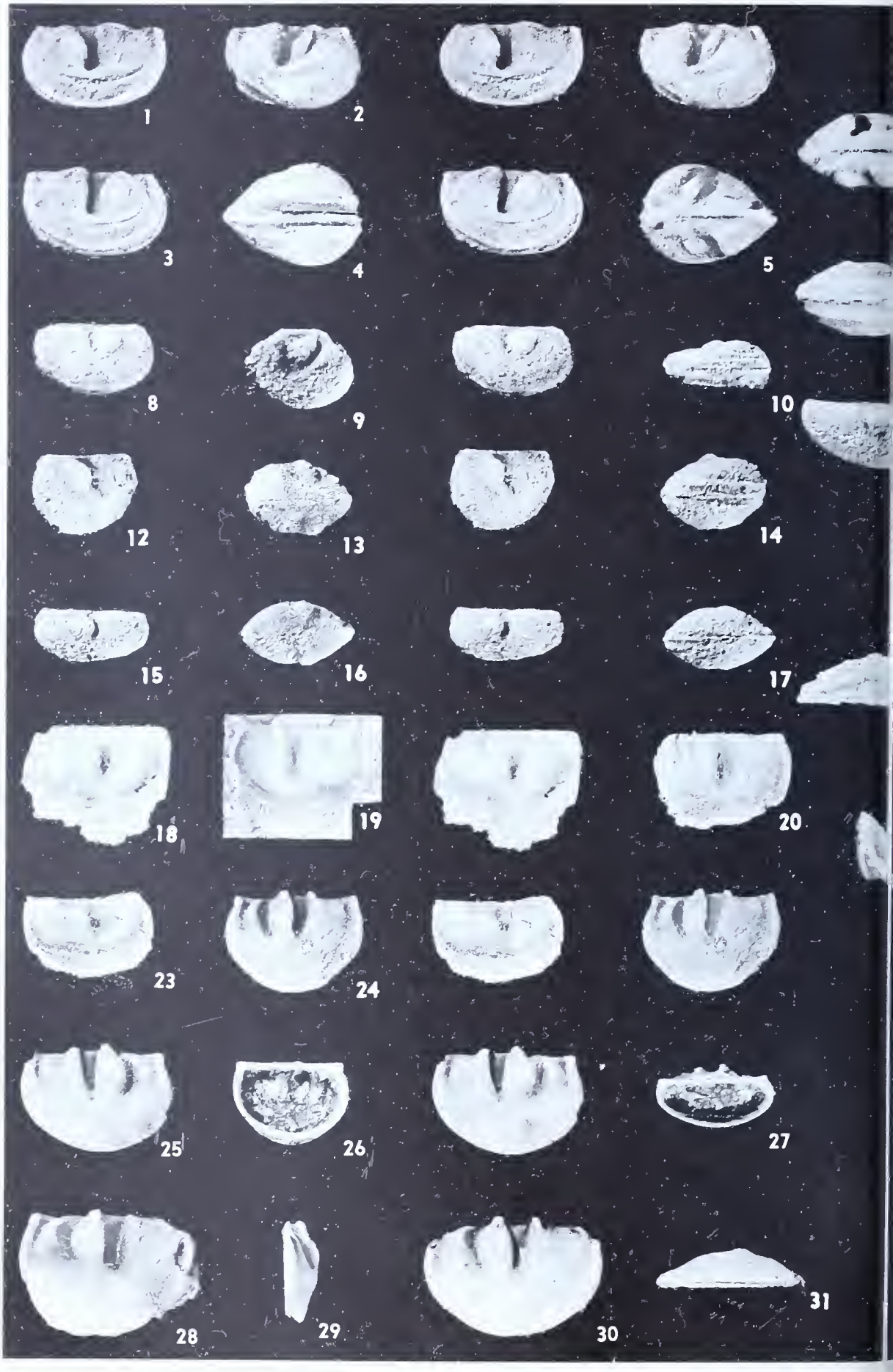
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EXPLANATION OF PLATE 2

All figures X 20

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Figure *1-7—Pseudobeyrichia ventrilirata* n. sp. *1, 3, 6, 7,* left lateral, right lateral, dorsal, and ventral views of male carapace, the holotype, USNM 143205; *2, 4, 5,* right lateral, ventral, and dorsal views of female carapace, paratype, USNM 143206a. From the upper member of the Mifflintown Formation, Locality 16 78

8-17—Pseudobeyrichia simplex n. sp. *8,* right lateral view of male carapace, holotype, USNM 143207; *9, 10,* lateral and dorsal views of partial female right valve, paratype, USNM 143208d; *11,* right lateral view of male carapace, paratype, USNM 143208a; *12-14,* left lateral, dorsal, and ventral views of male carapace, paratype, USNM 143208b, showing stubbier form; *15-17,* left lateral, dorsal, and ventral views of male carapace, paratype, USNM 143208c, showing very low and fat form. From the Bloomsburg Formation, Locality 14 78

18-23—Dibolbina lobata n. sp. *18,* lateral view of male left valve, holotype, USNM 143203; *19,* lateral view of male right valve, paratype, USNM 143204c; *20,* lateral view of a partial male left valve, paratype, USNM 143204a; *21-23,* ventral, posterior, and lateral views of a male left valve, paratype, USNM 143214b. All specimens except that used for Fig. 19 are from the upper member of the Mifflintown Formation, Locality 16; Fig. 19 from same rock unit at Locality 14 .. 76

24-31—Kyamodes? tricornis Ulrich and Bassler. *24, 29,* lateral and anterior views of male left valve; *25, 31,* lateral and ventral views of male right valve, ventral view showing ventral flange that fits in left valve; *26, 27,* lateral and dorsolateral views of interior of male left valve, showing breadth of valve contact and faint groove marking the inner position of the flange of the right valve. *28,* lateral view of a female left valve; *30,* lateral view of male left valve. From the upper member of the Mifflintown Formation, Locality 14 83

EXPLANATION OF PLATE 3

All figures X 15 unless otherwise indicated

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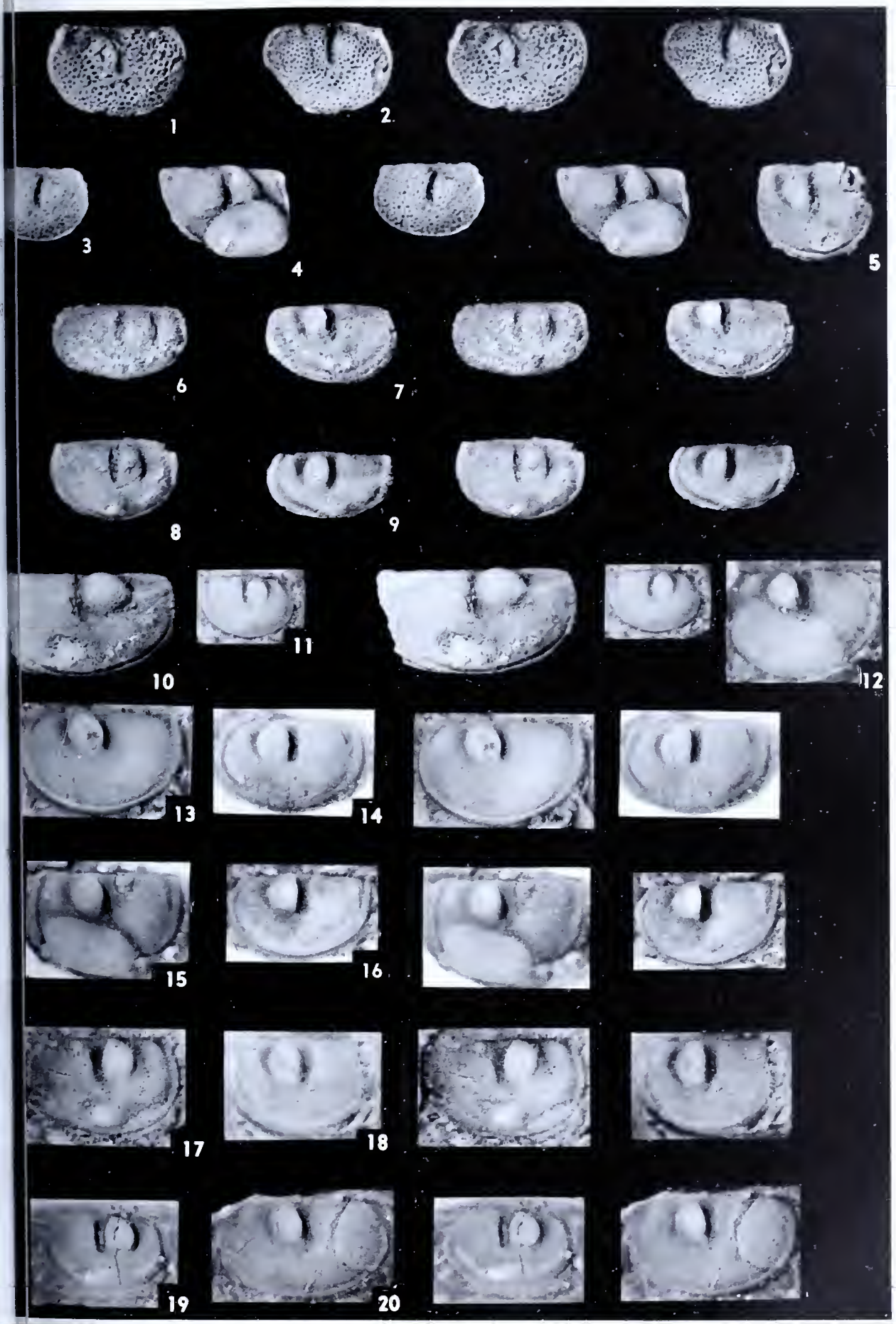
Figure *1-3—Bolbiprimitia subaequata* (Ulrich and Bassler). *1, 3,* left and right lateral views of male carapaces; *2,* right lateral view of female? carapace. X 20. From the Bloomsburg Formation, Locality 8 83

4-20—Kloedenia normalis Ulrich and Bassler. *4,* lateral view of female right valve showing small node on dimorphic swelling; *5,* lateral view of male left valve showing broken base of large node; *6, 7, 9,* lateral views of one right and two left male valves showing gradation from no ventral node to a very slight node; *8, 10,* lateral views of two male right valves showing a small and a very large ventral node. The specimens used for figures *4-10* all come from one sample in the Bloomsburg Formation, Locality 6.

11, 12, lateral views of the cotype male right valve and female left valve of *Kloedenia cacaponensis,* USNM 82991. From the *Drepanellina clarki* zone 1½ miles east of Great Cacapon, W. Va. *13-15,* lateral views of two male and one female left valves, cotypes of *Kloedenia normalis,* USNM 82997. From the Mifflintown and Wills Creek Formations, Pinto, Md. *16,* lateral view of male left valve, one of the cotypes of *Zygobeyrichia ventricornis* var. *obsoleta,* USNM 82976. From the Wills Creek Formation, 187 feet above the base, 3 miles west of Hancock, Md. *17-19,* lateral views of two male right valves and a male left valve, cotypes of *Zygobeyrichia ventricornis,* USNM 82974 and 82975. From the Wills Creek Formation, Pinto, Md. *20,* lateral view of a male left valve, holotype of *Kloedenia kenziensis,* USNM 83003. From the Mifflintown Formation, 100 feet below the top, Pinto, Md. Note the similarity among all the type specimens especially Figs. *14, 16, 18,* each of which originally belonged to a separate species or variety. 79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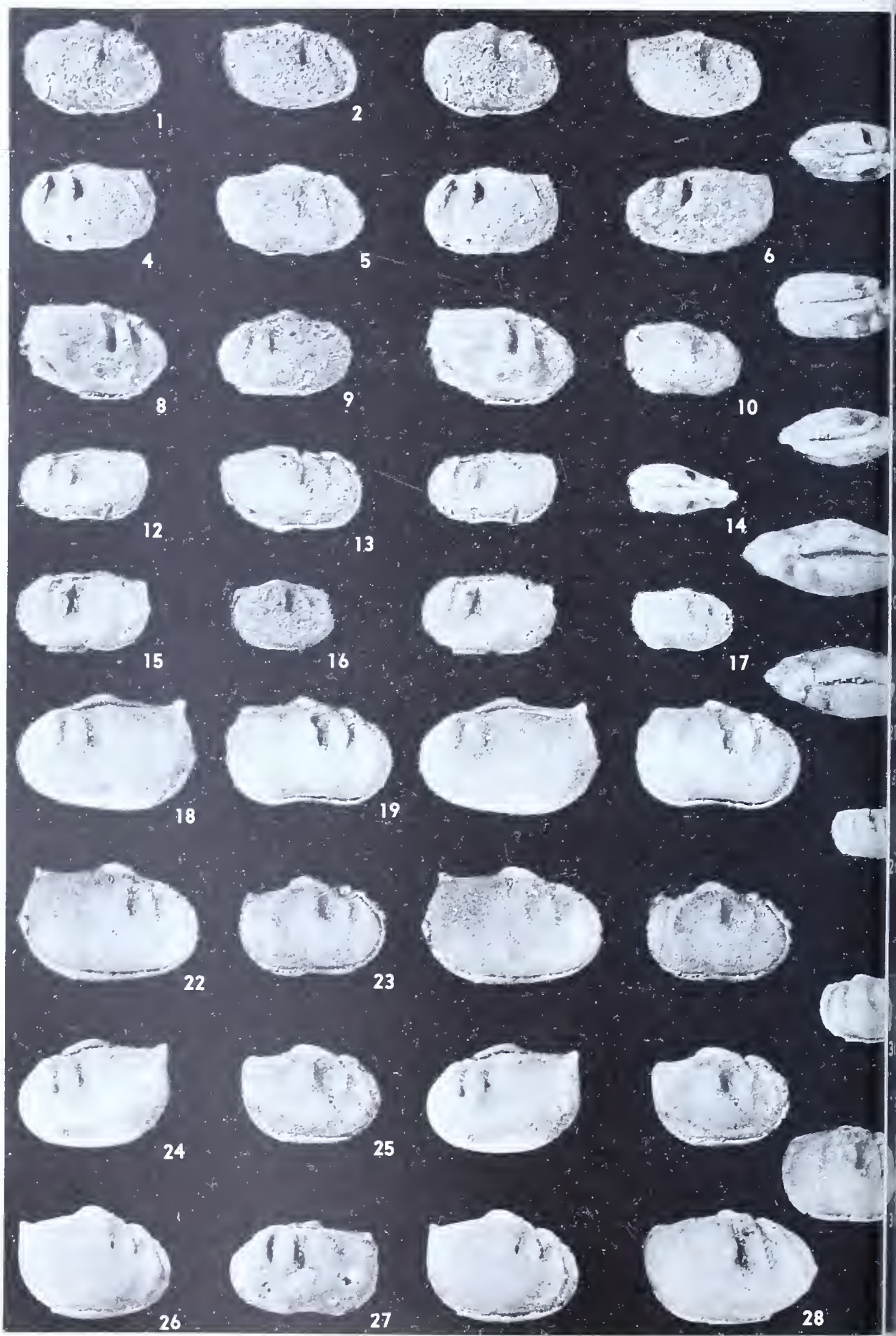
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EXPLANATION OF PLATE 4

All figures X 20

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Figure *1-9—Kloedenella berdanae* n. sp. *1,* right lateral view of male carapace, holotype, USNM 143211; *2,* right lateral view of female carapace, paratype, USNM 143212f; *3, 4,* dorsal and left lateral views of male carapace, paratype, USNM 143212a; *5,* right lateral view of male carapace, paratype USNM 143212b; *6,* left lateral view of female carapace, paratype, USNM 143212d; *7, 8,* dorsal and right lateral views of female carapace, paratype, USNM 143212e; *9,* left lateral view of male carapace, paratype, USNM 143212c. From the Bloomsburg Formation, Locality 8. 85

10-15—Kloedenella cristata n. sp. *10,* right lateral view of male, paratype, USNM 143210c; *11,* dorsal view of male carapace, paratype, USNM 143210d; *12,* left lateral view of male carapace, paratype, USNM 143210e; *13,* right lateral view of female carapace, paratype, USNM 143210a; *14,* dorsal view of female carapace, paratype, USNM 143210b; *15,* left lateral view of female, holotype; USNM 143209. From the Bloomsburg Formation, Locality 6. 84

16-31—Kloedenella gibberosa Ulrich and Bassler. *16, 17,* right lateral views of female and male carapaces, small variety from the Bloomsburg Formation, Locality 6; *18, 20, 22,* left lateral, dorsal, and right lateral views of male carapace. *21, 24, 26,* dorsal, left and right lateral views of female carapace. From the upper member of the Mifflintown Formation, Locality 14, showing rounded ventral margin, weak sulci, posterior cardinal angle spine, and swept back dorsal protuberance. *19, 27,* right and left lateral views of male carapaces; *28,* right lateral view of female carapace. From the Mifflintown Formation, Locality 19, 10 feet below top, showing sinuate ventral margin, deep sulci, and a low or nearly absent dorsal protuberance. *23, 25,* right lateral views of a male and female carapace from the Upper Member of the Mifflintown Formation, Locality 17, showing high, triangular dorsal protuberance that continues as a thin crest onto the posterodorsal area; *29-31,* right lateral views of different sized instars showing the S_3 and L_4 found only on the instars. The specimens are from the Mifflintown Formation, Locality 19, 10 feet below the top. 86

EXPLANATION OF PLATE 5

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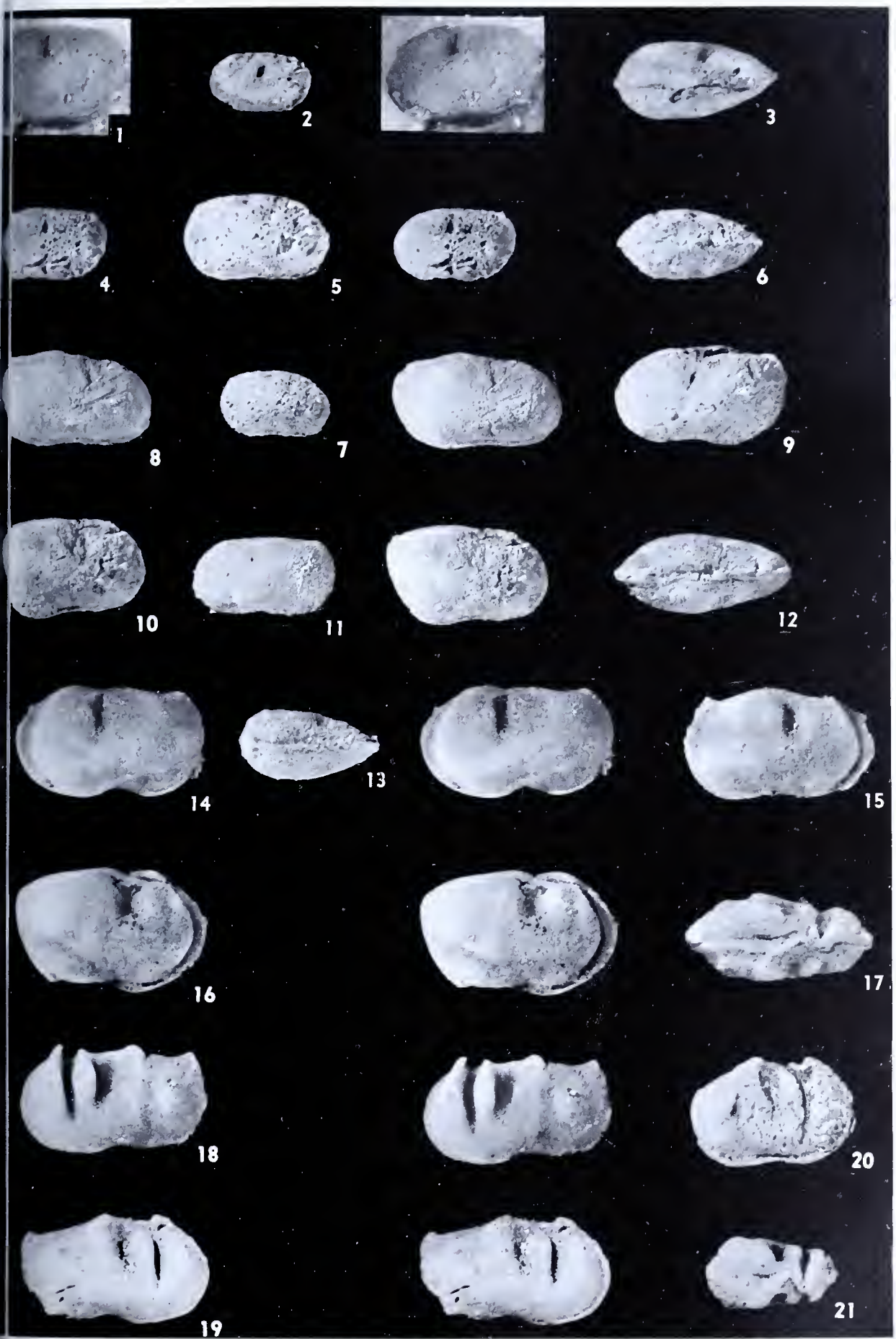
Figure *1-7—Eukloedenella curta* Ulrich and Bassler. *1,* left lateral view of male carapace, holotype, USNM 63624, from the Wills Creek Formation, 45 feet above the base, Pinto, Md.; *2,* left lateral view of instar showing fine punctae; *3,* dorsal view of female carapace; *4,* left lateral view of male carapace; *5-7,* right lateral, dorsal, and right lateral views of a male carapace. All X 20 except Fig. 7. Fig. 7 X 15 to show size comparison with *Eukloedenella umbilicata.* From Wills Creek Formation, Locality 18, 32 feet above base. 88

8-13—Eukloedenella umbilicata Ulrich and Bassler. *8, 9, 12,* right lateral, left lateral, and dorsal views of male carapaces; *10, 13,* right lateral, and dorsal views of female carapaces. From the upper member of the Mifflintown Formation, Locality 16. *11,* left lateral view of male carapace, from the upper member of the Mifflintown Formation, Locality 14. X 15. 89

14-16—Eukloedenella sinuata Ulrich and Bassler. *14, 15,* left and right lateral views of male carapaces; *16,* right lateral view of a female carapace. From the upper member of the Mifflintown Formation, Locality 14. X 20. 88

17-21—Dizygopleura gibba Ulrich and Bassler. *17, 19,* dorsal and right lateral views of male carapaces; *20, 21,* right lateral and dorsal views of female? carapaces. From the upper member of the Mifflintown Formation, Locality 16. *18,* left lateral view of male carapace from the upper member of the Mifflintown Formation, Locality 14. X 20. 90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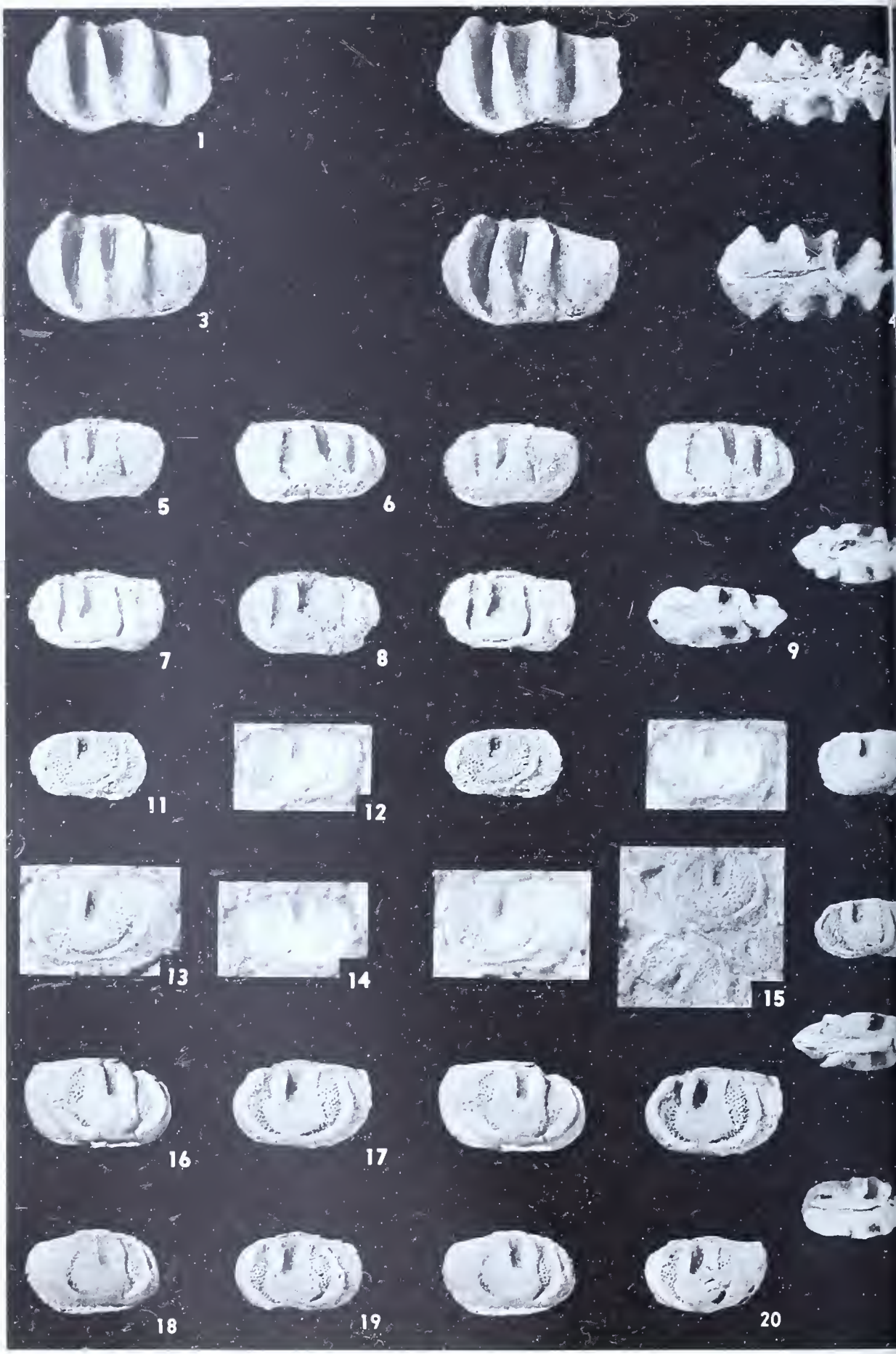
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EXPLANATION OF PLATE 6

All figures X 20

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Figure *1-4—Dizygopleura perrugosa* Ulrich and Bassler. *1, 2,* left lateral and dorsal views of male carapaces, *3, 4,* left lateral and dorsal views of a female carapace. From the upper member of the Mifflintown Formation, Locality 16. 91

5-10—Dizygopleura halli (Jones). *5, 8,* left lateral views of female carapaces, *6, 7,* right and left lateral views of male carapaces, *9, 10,* dorsal views of a female and a male carapace. From the Bloomsburg Formation, Locality 8. 90

11-15—Dizygopleura? pulchella (Ulrich and Bassler). *11, 12,* left lateral views of two male carapaces; *13, 14,* left and right lateral views of female carapaces; *15,* left lateral views of two male valves, the original specimens on which *Bollia pulchella* Ulrich and Bassler was based. This figure duplicates Fig. 26, Pl. 37 of Ulrich and Bassler (1923). All specimens from the holotype slab, USNM 63696, from the Wills Creek Formation, 125 feet above the base, Pinto, Md. 92

16-24—Dizygopleura punctella n. sp. *16,* right lateral view of male carapace, holotype, USNM 143213; *17,* left lateral view of male carapace, paratype, USNM 143214a; *18,* right lateral view of female carapace, paratype, USNM 143215a; *19,* left lateral view of male carapace, paratype, USNM 143214b; *20,* left lateral view of female carapace, paratype, USNM 143215b; *21,* left lateral view of male carapace, paratype, USNM 143214c, showing absence of S_3; *22,* left lateral view of male, paratype, USNM 143214d, showing narrow S_3; *23,* dorsal view of male carapace, paratype, USNM 143214e; *24,* dorsal view of female carapace, paratype, USNM 143215c. The specimens used for Figs. *21, 22,* are from the Bloomsburg Formation, Locality 8. The other specimens are from the Bloomsburg Formation, Locality 6. 93

EXPLANATION OF PLATE 7

All figures X 20 unless otherwise indicated

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Figure *1-5—Dizygopleura swartzi* Ulrich and Bassler. *1, 5,* right lateral and dorsal views of a male valve; *2, 4,* dorsal and left lateral views of a female carapace; *3,* right lateral view of small instar, showing more pronounced S_3. From the Mifflintown Formation, 10 feet below the top, Locality 19. 94

6-10—Dizygopleura unipunctata Ulrich and Bassler. *6, 8, 9,* right lateral, dorsal, and left lateral views of a male carapace; *7, 10,* left lateral and dorsal views of a female left valve. From the upper member of the Mifflintown Formation, Locality 17. 95

11-18—Dizygopleura ventrisulcata n. sp. *11,* right lateral view of male carapace, holotype, USNM 143216; *12,* left lateral view of male carapace, paratype, USNM 143217a; *13,* ventral view of male carapace, paratype, USNM 143217b; *14,* dorsal view of male carapace, paratype, USNM 143217c; *15,* ventral view of female carapace, paratype, USNM 143218a; *16,* dorsal view of female carapace, USNM 143218b; *17,* right lateral view of female carapace, paratype, USNM 143218c; *18,* left lateral view of female carapace, paratype, USNM 143218d. From the Bloomsburg Formation, Locality 6. 95

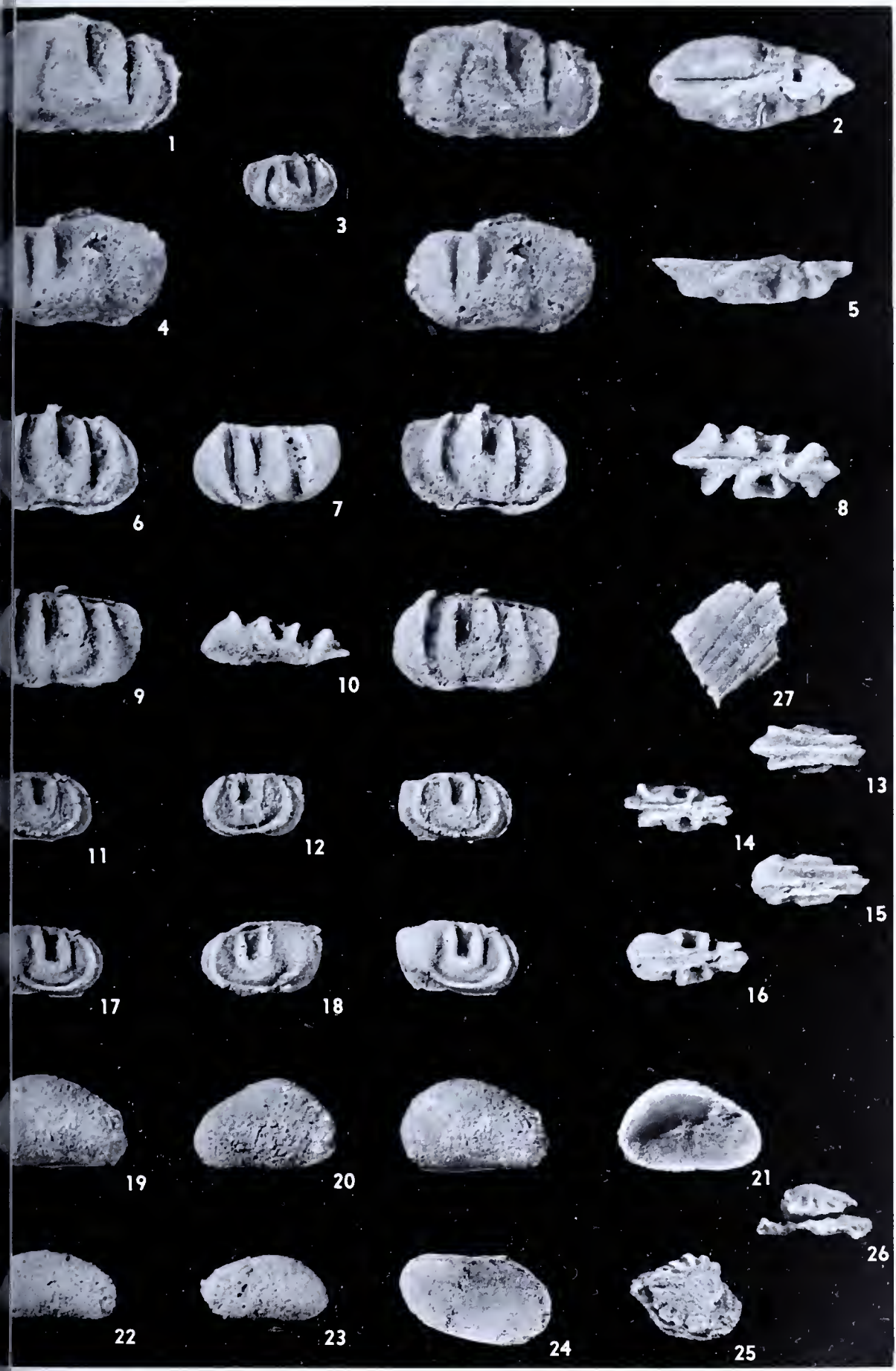
19-21—"Bythocypris" philipsiana (Jones and Holl). *19, 20,* right and left lateral views of two carapaces; *21,* interior view of left valve; from upper member of the Bloomsburg Formation, Locality 16. 97

22, 23—"Bythocypris" cf. *"B" pergracilis* Ulrich and Bassler. Right and left lateral views of two carapaces, from the Bloomsburg Formation, Locality 8. 97

24—Herrmannina willsensis (Ulrich and Bassler). Lateral view of right valve, X 5, from the upper member of the Mifflintown Formation, Locality 14. 96

25, 26—?Agnathid scale. Views from above and from the side. From the upper member of the Mifflintown Formation, Locality 14. 98

27—Heterostracid "Fish scale." View from above. X 15. From the Bloomsburg Formation, Locality 12 98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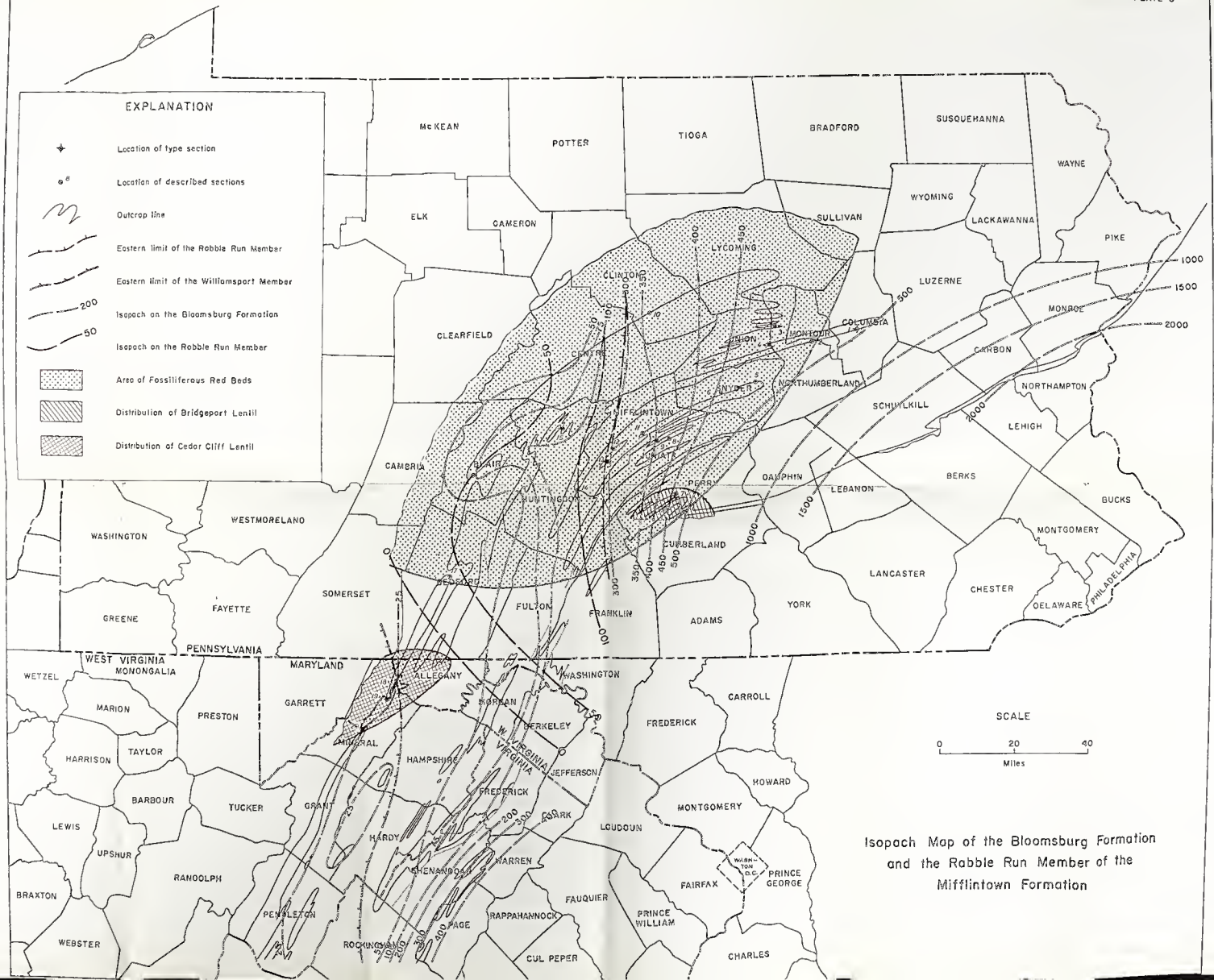

Isopach Map of the Bloomsburg Formation and the Rabble Run Member of the Mifflintown Formation